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# THE PROCEEDINGS

OF THE

# UNITED STATES NAVAL INSTITUTE.

**Vol. XIII., No. 1. 1887. Whole No. 40.**


## U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

JANUARY 5, 1887.

COMMANDER WM. T. SAMPSON, U. S. N., Vice-President U. S. N. I., in the Chair.

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The meeting was called to order at 8 P. M., and the chairman requested the Secretary to read the paper before the Institute.

Lieutenant JNO. W. DANENHOWER.—*Mr. Chairman and Gentlemen*:—I desire to state before reading this paper that it originated by invitation of the Institute, for the purpose of producing a profitable discussion on the subject of Steel for Heavy Guns. About one hundred and fifty corrected galley-proofs of the paper were sent to the friends and supporters of the author, as well as to other steel manufacturers and ordnance experts who were invited to be present or to communicate their views. The author is a well-known member of the American Society of Civil Engineers and of the American Institute of Mining Engineers, who has devoted much time to the subject of steel for structural purposes. I regret extremely that he is unable to be present at this meeting, for his personality and the earnestness of his convictions would add great force to his paper.

# STEEL FOR HEAVY GUNS.

By Edward Bates Dorsey, C. E.

During the last four years I have been obliged for professional purposes to examine as thoroughly as possible into the suitability of steel for structural purposes. This investigation obliged me to make several trips to Europe, as I was anxious to get the opinion and experience of all the principal steel workers of the world.

The word "steel" as used now is very comprehensive, embracing material running from a very pure quality of iron, with little or no carbon and a tensile strength of 55,000 pounds, up to tool steel with a high percentage of carbon and a tensile strength of over 150,000 pounds. In this paper, for convenience, I shall use the terms "mild steel" and "hard steel" with the following meanings:

Mild steel is steel with a very low percentage of carbon, incapable of taking temper; will bend double, when cold, without fracture, and having a tensile strength of from 55,000 to 65,000 pounds.

Hard steel is steel with a variable percentage of carbon; will take temper, more or less hard, and having a tensile strength of over 90,000 pounds.

Tensile strength, whenever used in this paper, will mean, unless otherwise stated, the ultimate tensile strength per square inch of section in pounds.

All workers in steel will admit the following axioms to be true and indisputable: 1st. The treacherous and capricious qualities of steel increase with its tensile strength, being zero about 60,000 pounds tensile strength. 2d. The treacherous and capricious qualities of steel increase as the size, thickness or section of piece increases. 3d. The greatest reduction of size, thickness or section by work within limits will give the greatest increased tensile strength. 4th. With the same amount of work within limits, the tensile strength decreases as the size, thickness or section increases.

Mild steel is the most reliable of all cheap metals. It can be badly worked and maltreated with impunity, yet it can be trusted under all circumstances. Hard steel, on the contrary, requires the most delicate manipulation, and even then it will, when in large pieces, break and crack without any apparent cause or reason. In all shops

that have worked large-sized pieces of it, there are told many stories of how it cracked when it was completely at rest, etc. This has been proved by the recent failures of the steel guns in England, all failing under little or no strain.

Gunmakers are now apparently committing the same errors that civil engineers did when they first commenced to use steel for structural purposes. They found a new, cheap and strong metal, but their use of high-tensile-strength steel temporarily brought this material into disrepute. Nearly all failures in its use can be ascribed to this cause.

The specifications of the Ordnance Office of the War Department ask for bids for hoops for eight-inch guns, the maximum thickness being $4\frac{9}{16}$ inches. (The promised specifications from the Ordnance Office of the Navy Department have not been received.) These specifications call for tensile strength not less than 100,000 pounds per square inch; elongation after rupture not less than 12 per centum in specimens six inches in length between shoulders; all to be of open-hearth steel.

Without the oil temper this quality of hard steel would not be used by any bridgebuilder, boilermaker, shipbuilder, or architect where the strain or work is comparatively steady and regular compared to the heavy, sudden shocks caused by the service charge of powder in large guns. As yet, the experiments showing the actual *improvement* on hard steel by the oil temper in large pieces* or masses are not sufficiently thorough or complete to be conclusive, or to induce the general use of an unreliable material. The advocates of the use of hard steel claim that it is much improved and its nature and character entirely changed by immersion while hot in an oil bath. Unquestionably this has a very beneficial effect upon small pieces. Hard steel is one of the most compact of all known

* The circular from the United States Navy Department of August 21, 1886, inviting bids for gun forgings, does not give the dimensions; it, however, gives the approximate weight as follows:

"These forgings are to be delivered rough bored and turned, and when in that state the heaviest forging which enters into the construction of a gun of each of the desired calibres will be about as follows:

| | |
|---|---|
| 6-inch . . . . | $3\frac{1}{4}$ tons. |
| 8-inch . . . . | 5 tons. |
| 10-inch . . . . | $9\frac{1}{2}$ tons. |
| $10\frac{1}{2}$-inch . . . . | $9\frac{3}{4}$ tons. |
| 12-inch . . . . | $12\frac{1}{2}$ tons." |

substances. Can the oil of the bath or its good effect penetrate sufficiently far into the interior of this compact material in large masses so as to make a complete change in its character? May not the beneficial effect shown be only on or near the surface—skin-deep?

In my judgment, the great improvements reported in the working qualities of hard steel caused by the oil bath on large pieces have not been conclusively demonstrated, especially in face of the recent failures in large steel guns. On the contrary, do not these failures show that hard steel still retains its character unchanged for capriciousness and unreliability? Before spending the millions of dollars for new guns for our Army and Navy, it would be well to test more thoroughly the supposed great improvement made in the character of large masses of hard steel by the immersion in the oil bath. There is no question but that hard steel is entirely too unreliable to be used in its natural state in large pieces for any kind of structural work. These tests and experiments should show conclusively that the oil temper changes a structural material unsafe for the most simple work into material reliable for the most trying and difficult service. If these experiments do not show this beyond question, then hard steel should not be used for the large guns.

The *Lloyds' Register* of England have probably more practical knowledge of steel than any person, firm, or corporation. Mr. Parker, their chief engineer, who has been a most indefatigable experimenter and investigator in steel, was among the first to advise its use in marine architecture, especially for boilers. Notwithstanding their long experience, the following order was issued last month: "The Committee of Lloyds' Registry for British and Foreign Shipping, having been advised by their technical engineering staff that it was fitting that there should be greater stringency as to the tests to which steel for boilers is subjected, have issued modified instructions on the subject. Formerly all steel for boiler plates was required to have an ultimate strength of not less than 26 (long) tons nor more than 30 tons per square inch of section, with an ultimate elongation of not less than 20 per cent. in a length of eight inches. In the matter of elongation their requirements remain the same, but as regards the breaking strain a sliding scale is adopted as follows: The material of stays and of plates not exceeding 1 inch in thickness is to have an ultimate tensile strength of not less than 26 and not more than 30 tons per square inch of section; in plates above 1 inch and not more than 1 [illegible] inches in thickness, the ultimate strength must not be less

ample to originate the fatal cracks so common and unaccountable in hard steel. The formation of these cracks will be accelerated by the firing of the heavy-service or fighting charge of the gun. Of course, if the gun is entirely protected from the fire of small cannon or machine guns, this risk will be avoided; but, owing to the great length of modern guns, it is doubtful if its entire length can be protected from machine-gun fire. Before finally adopting this class of metal for our large guns, it would be well to make experiments, to see how guns made from it would act under the same conditions as in battle. They should be subjected to a severe fire from small cannon and machine guns, and afterwards fired repeatedly with the usual severe fighting charge.

## CONCLUSIONS.

If it is necessary or desirable to have light guns, these can be made by using many thin hoops, or cylinders, made of mild steel, building one over the other on the barrel, instead of the thick hoop of hard steel, as called for in the Ordnance Specifications. The strength and reliability of the gun will increase *for the same weight proportionally as the thickness of the hoops decreases* to a practical limit. All that is necessary is to find out by experiment what is the proper thickness of hoops consistent with weight, strength and cost. This thickness may be found to vary with the size and use of the gun. The gun to be used in fortifications need not be so light as that for use on shipboard. Suppose, for illustration, that instead of using thick hoops of hard steel, twelve hoops made of mild steel be used, placing one over the other. By putting the proper amount of work on these, the tensile strength can be raised very high without impairing the quality; moreover, if by any chance one or two of these hoops should break or fail, the remaining ones will be ample to sustain the strain, as they would always be used with a large factor of safety. A gun, if properly constructed and proportioned, made in this manner of mild steel, could not fail, even with any reasonable amount of bad treatment. This is a practical application of the old adages: "In union there is strength"; and "Not to put all your eggs in one basket."

The steel that I advise to be used for making guns is the ordinary mild steel of commerce, made by a great many establishments in the United States in large quantities, and which can be had at any time in any desired quantity. It is now selling at about sixty dollars per ton.

The hard steel called for in the Specifications is a special product, not used to any extent in commerce, being too unreliable and expensive for any commercial use. It must be manufactured to order, and, owing to this and to the severe specifications, the cost will be great.

By the use of many and thin hoops, or cylinders, of mild steel, properly built up and proportioned, a gun can be made that will be at all times safe, reliable, and unfailing. If hard steel, or steel of high tensile strength, in thick hoops, is used, the gun will be more costly, and of greater theoretical strength, but practically much weaker, and will fail when least expected, and without any apparent cause or reason. If it is necessary to have thick hoops, as called for in the Ordnance Specifications, make them of mild steel, giving the necessary strength by additional material; this may make a heavier gun, but it will always be safe and reliable. Hard steel should not be used until much more is definitely known of the *supposed* improvement of the oil temper on large pieces or masses of metal.

## DISCUSSION.

The chairman addressed the meeting and stated that a large number of replies had been received from steel makers and experts to whom proofs of Mr. Dorsey's paper had been sent; that he was glad to see present a number of prominent gentlemen who had responded to the invitation, and that the Board of Control had suggested an arrangement for the meeting which he would follow in calling upon speakers to take the floor. He then requested Lieut. C. R. Miles, U. S. N., to read communications received by the Institute, and the following were presented to the meeting, viz.:

### Dr. RICHARD J. GATLING, *The Gatling Gun Company, Hartford, Conn.*

I shall not attempt to add anything to what has been so well and appropriately said by Mr. Dorsey in his lecture. I am wholly in accord with his views.

I believe that a mild or low grade of soft steel will be a cheaper and better material for making heavy guns (especially guns for fortifications) than hard steel. I have found in my experience that hard steel, even when it is well and carefully tempered, is far more

treacherous and easily broken or fractured when subjected to violent shocks than soft or mild steel. For instance, firing-pins and gun-lock hammers, when made from well-tempered hard steel, are less durable and more liable to break than when made of mild steel.

It is difficult to temper large masses of hard steel so as to have all parts of an even temper or homogeneous. Although such steel has great tensile strength, nevertheless it is quite brittle, and when subjected to sudden and violent strains is more liable to break or crack than soft or mild steel.

When large guns are fired with heavy charges, there is great strain on the parts, causing more or less vibration of the whole structure of the gun. In other words, the repeated firing of a gun will produce what is known as the fatigue of metal, and when that occurs and the metal becomes more or less crystallized (and which in my judgment is more liable to occur, and to a greater degree, in guns made of hard than in those made of mild steel), the lifetime of the gun may be said to be at an end. At all events, when a gun gets in such a condition, it becomes liable to burst, and is dangerous to the men using it.

Professor R. H. THURSTON (*formerly of the U. S. N. Engineer Corps*), *Director of Sibley College, Cornell University.*

I have read the paper of Mr. Dorsey with great interest, and am very strongly in sympathy with his ideas, as there presented. I have had a tolerably long and extensive experience with modern steels, as well as with all the other common materials of engineering construction, and am fully convinced that, in the absence of more definite and much more satisfactory knowledge of the precise effect of the several elements present in the steels, both as affecting their behavior under slowly applied and rapidly imposed stresses, and their endurance for long periods of time, loaded or unloaded—for the effect of time on the unloaded metal is sometimes serious—the only safe course is to use such steel as we know to be safe under all known conditions and indefinitely as to time. We learned, after some years of persistent attempt to make use of the stronger steels in steel rails and in steam-boiler construction, that it was unsafe to use them; we are now only beginning to see that they are just as treacherous in other constructions, and that ordnance is no exception to the thus far apparently universal rule. We have come down to the use of a metal which is not steel at all, in the proper sense, for all other constructions exposed to heavy stresses—a metal to which we should apply the

name given by the International Commission of Engineers, "ingot iron." It is simply a homogeneous iron, an iron free from slag and fibre, and thus possessed of all the good qualities of the best puddled irons, without any of their defects, except, in some cases, such as may have been brought in by the introduction of an excess of manganese, or the use of ores containing phosphorus in noticeable quantities. It has been the universal experience of engineers using steel for civil constructions that the further we recede from the character, as to composition and strength, of wrought iron in such cases, the less safe and satisfactory is the result. In seeking tenacity we surrender ductility and resilience.

There are, undoubtedly, some evidences of the practicability of making successful application of harder steels. Mr. Wm. Metcalf has found that the best steel for steam-hammer piston rods—where the blows are severe and the jar and vibration perhaps greater than in any other case familiar to the civilian engineer—is steel made in the crucible and containing about 0.8 per cent. carbon. It is possible that this metal can be used in ordnance; but it would be wise to settle that question on the small scale first, by using it in steel howitzers, and to defer the making of a large gun until the smaller sizes had been proved safe. The process of oil-tempering is one which has given remarkable results on a small mass of even high tool-steel; but it still remains to be shown that great masses are to be safely treated for ordnance purposes in this way. I think it very possible that it may prove that they may; but it is certain that the doubt remains, as yet, too serious to permit the expenditure of large sums on the assumption that we may absolutely rely upon such methods of securing strength, elasticity, homogeneousness, and permanence of good quality. I should certainly not urge the suspension of all efforts in that direction; but I should, by all means, advise caution, in construction, in going ahead of our experimental knowledge.

The requisites of good ordnance steel are, in my judgment: First, permanence of such good qualities as the metal may at the beginning possess; then I would look for a certain elasticity within small ranges of distortion; ductility for larger changes of form; perfect uniformity; and, last of all, a certain maximum strength consistent with the possession of these still more essential properties. Ingot iron at 60,000 pounds per square inch, with the ductility and elasticity, the homogeneousness and the permanence of good quality which we know it may be made to offer, is vastly to be preferred to stronger

steels deficient in these other essentials. It will make a better gun than the built-up iron guns of Armstrong and other makers, which, as now seems certain, were more serviceable than the best of recent steel ordnance made of high-grade steel. It seems even doubtful whether Krupp's guns are, on the whole, a better class of ordnance than the thoroughly well-constructed wrought-iron gun. The effect of stress and of time on the wrought iron is known to be at least not injurious; it is not so certain that this can be said of any steel gun, of whatever grade above that of the best ingot iron, low in manganese.

I have always had great faith in the methods of securing density, homogeneousness, strength, and elasticity, practised by Whitworth and his followers. It is now something like fifteen years since I made a report, by request of the Admiral, to the Navy Department, after a summer abroad, and a visit to the Whitworth establishment, urging that the Department take immediate steps to secure the necessary means of introducing this process, at least experimentally, into our own country, for the main purpose of obtaining ordnance that might be relied upon to do good work with equal certainty on all occasions and at all ages of gun, and the subject has been often revived since then. The supineness of the British, as well as other governments, including our own, in this matter, has always appeared to me marvellous. The work of Whitworth, for nearly a generation, has proved the value of his methods so absolutely; the introduction of his steels into constructions in civil and mechanical engineering has gone on so steadily and satisfactorily, and the grand facts asserted by him have been so many times, so constantly, proven, that it seems hardly less than a miracle of unbelief that could have prevented our own and other governments availing themselves of it for their own purposes, to which the process so perfectly and specially adapts itself. It is barely possible that other means may be found of securing equally well the qualities which to-day make the Whitworth process and its product peculiar in their excellence and effectiveness; but, while we are waiting for them, the world moves, and we are relatively going astern. I think that there are several inventors in this country who are working in that line of improvement, and it would seem easy for our Government to secure all the aid that it may desire in developing its own system of manufacture of heavy ordnance on well-understood and thoroughly proven lines.

THOMAS C. CLARKE, C. E., *Union Bridge Company, New York.*

The undersigned concurs with Mr. Dorsey in his views as to the superior uniformity of a low-carbon or "mild" steel.

A sufficient number of experiments have been made by bridge constructors to establish this as a fact beyond the shadow of a doubt.

By mild steel, we mean steel having an ultimate tensile strength in large sections of not over 65,000 pounds per square inch, an elastic limit of 35,000 to 40,000 pounds, and a stretch in full-sized sections of at least $\frac{20}{100}$ in 10 feet, and reduction of area at point of fracture of about $\frac{50}{100}$.

The process of upsetting and forging eyes on the heads of bars causes a *flow* of the particles of steel to an unusual extent, and sometimes involves hammering at a blue heat. Yet it is a very uncommon thing for a steel eye bar made of this material to break in the eye; while steel eye bars made of 90,000 pounds steel would behave most unaccountably, one breaking in the eye with 40,000 pounds to the square inch area of bar, and another running up to over 90,000 pounds.

It seems reasonable to suppose that high steel forged into hoops for guns would behave in an uncertain manner, while low steel would give uniform results.

The undersigned, never having had any experience in the manufacture of such hoops, can only reason from analogy.

THOMAS C. CLARKE,
*Member Am. Soc. Civ. Eng.; Institution Civ. Eng., London;*
*Am. Phil. Soc.*

*December* 17, 1886.

Professor THOMAS EGLESTON, *School of Mines, Columbia College, New York.*

I have yours of December 9th, with the enclosed document inviting me to be present January 5th, to take part in the discussion of the question of steel for heavy guns. I regret that I am unable to be present at Annapolis to take part in the discussion, and all the more so as, since before the Government commenced agitating this question, I had been very much interested in it. Independently of the researches which I have made in this matter, I have been several times to Europe and have studied this question in almost every large manufactory of ordnance there.

For the last eight years I have been earnestly advocating a test commission as the only way of settling this question, and many others of a similar and equally important character.

As I have said in some of my papers on this subject, there is every reason why steel guns should be manufactured; but there is much to be done before we can successfully make them in this country. General Rodman made cast-iron guns of a superior quality and educated the country up to his ideas. The limit between steel and cast iron is not wide, but the difficulty of managing it is no greater now than of learning how to make cast-iron guns of large size was then. We shall have to do for steel what General Rodman did for cast iron. One of the greatest difficulties in manufacturing steel in large masses is that people insist upon hammering it, and, so far as large masses of steel are concerned, they never should be touched with a hammer in any stage of their manufacture. Hammering generally makes steel brittle, except in very small sizes, independently of the whole question of blue temper. I have seen masses of twenty-five tons of steel cast and pressed so that tests throughout the steel showed absolute uniformity and very great toughness, with no tendency towards cracking; and, on the other hand, I have in my possession at the present time a photograph of a very large hammered crank pin, made of the best of steel, under the most favorable circumstances, which is riddled with cracks in every direction, some of which were ten inches long and half of an inch wide. The greatest difficulties in the matter are the questions of occluded gases, liquation of the elements, which takes place, as is not generally understood, not only from the top towards the bottom, but from the sides towards the centre of very large castings. This is, however, a purely mechanical difficulty, which can be entirely overcome.

I am glad your Institute has raised the question and brought it to the attention of naval men, for the only thing that is wanting in this country for the manufacture of such material is the certain patronage of the Government. There is no place in the world where there is finer material than there is in this country. There are no better steelmakers in the world than some of those who make high-grade steel in the United States. The ability and material are all here, but the demand for large masses of steel can only come from the Government of the United States; and, therefore, as it is the only customer possible, it should guarantee for a period of years orders to an amount sufficient to justify capitalists in erecting the necessary

plant. When these conditions are fulfilled there will be no real difficulty in solving the problem of heavy steel ordnance better and more economically than has been done by any of the governments of Europe. I have seen too many of these heavy guns made, and too much of the various metallurgical establishments of the Government of the United States, to ever believe that it can manufacture such ordnance in its own shops. It will have to be done by private enterprise, supported by Government patronage, if at all. I have, unfortunately, been on board several cruisers in Europe which could, without fear, enter any port of the United States, including New York, and levy any tribute they chose, and get safely away for the time being. This is mortifying, in view of the fact that we have, as is acknowledged by all the governments of the world, greater resources and greater mechanical engineering ability than can be found anywhere else. After the close of the war I was fortunate enough to be a member of the commission which examined the armaments of the forts of the United States, and saw, under injunction of secrecy, thirteen inches of iron pierced for the first time. I went immediately after that to Europe in time to hear of the experiments at Shoeburyness, where nine inches of iron were pierced, which was considered an immense feat. There is no reason why the United States should not be as far ahead of the rest of the world now as then; but, unfortunately, we have rested satisfied with what we have done, and have lagged behind.

As you see, the question of the use of steel for guns is not a new one with me. I have been perfectly satisfied for a number of years that steel guns of any calibre could be manufactured in the United States, if the requisite conditions were to be fulfilled. But there is one thing that must *not* be done, which is, that steel in large masses must *not* be hammered; and as it is impossible to entirely prevent the occlusion of large quantities of gas and the consequent blow-holes, and the concentration of impurities by liquation from the top towards the bottom and from the sides towards the centre, powerful presses are the only way in which such large masses of steel should be treated.

Yours truly, THOS. EGLESTON.

MR. WM. HENRY BROWN, *Manufacturer of Seamless Steel Tubes, Jersey City, N. J.*

*Gentlemen*:—In addressing you upon the subject of steel for heavy guns, I must be permitted to so largely differ with the construction

of guns as now existing generally, that I feel, unless I am present with deeds, my sayings will not command the attention they deserve. Experience has been my teacher, and founder of all I say. I have been a worker of mild steel, from the seamless knife-handle up to the cylinder or tube twelve inches in diameter, and in thickness from half an inch down to the paper I am writing on. As a manufacturer of all metals during my life, and having the experience of my ancestors before me, I am prepared to demonstrate that you can do anything with mild steel that you can do with copper, and on account of its greater tensile strength it will bear a greater reduction in cold-working. Mild steel is in its infancy for all structural work. It is the coming metal of the age for all uses, and the only cheap metal that will bear any amount of abuse with impunity. If this mild steel is carried into structural use without changing its homogeneity in the process, we have met a large demand. This is what we claim to have accomplished, adding thereto, by compression and drawing, an increased tensile strength that permeates alike the entire thickness *uniformly*, without shock or chill, easily reaching 100,000 pounds, or over, tensile strength to the square inch. The oil-temper is only a chill on the surface, does not give uniformity throughout, and in hard steel it is capricious. Shock, expansion and contraction destroy the structure in a short time, and in its natural state is too unreliable for any structural work. Such has been my experience. In entering upon this discussion for heavy guns, I take the position that you cannot *cast* hard steel into form on account of *cavity*, and that hoops and bands are not reliable, and have no longitudinal support.

But we can take a disk of mild steel, and by forming it up hot, and by compressing and drawing it cold, finish it so as to gain a tensile strength that will reach any demand required for safety and reliability. Let me take up the construction of a 6-inch gun (although it is equally adapted to all guns), and consider the tube bore and rifling as satisfactorily constructed. I take a circular plate of steel boiler-plate, say one-half inch, more or less, in thickness, heat it, and dish it up by hydraulic force. This process is repeated, a smaller die and punch being used, until the shell has reached the required diameter and length for finishing. In a like manner similar shells of a larger size are produced for reinforcing to any extent desired. Taking the tube bore of the gun which we desire to cover, and which constitutes the mandrel for compressing and drawing the first shell, I cover the tube with the shell, and, to make it more firm, pass it through a

Calculation for a six-inch by six-foot steel gun, each plate being one inch thick:

| | Weight lbs. | Diam. of Plate (inches). | Combined Resistance per sq. in. lbs. |
|---|---|---|---|
| First shell | 451 | 45 | 28,000 |
| Second shell | 400 | 43 | 50,000 |
| Third shell | 300 | 38 | 68,000 |
| Fourth shell | 270 | 33 | 82,000 |

The total weight would then be only 1421 pounds, while the resistance would range from 28,000 pounds per square inch at the muzzle to 82,000 pounds at the butt. The figures denoting the power of resistance are obtained by deducting from the tensile strength of steel 100,000 pounds per square inch, the multiplied area of the inner surface. W. H. B.

Mr. S. T. WELLMAN, *Superintendent of the Otis Iron and Steel Company, Cleveland, Ohio.*

It seems to me the argument that Mr. Dorsey holds out is, that because mild steel has been proved to be the best material for structural purposes and for steam boilers, therefore it is the best for heavy guns. It seems to me that the kind of strain put upon steel boiler-plates and structural material is of an entirely different kind from that to which gun steel is subjected, the former having to withstand nothing but steady loads, while the latter is continually subjected to shocks, and those of the most severe kind. In our line of business we have had no experience with steel for heavy guns. The nearest thing to the kind of shock to which gun steel is subjected is that which steam-hammer piston rods have to stand. It has been repeatedly proved, by many experiments with both kinds of steel, that hard steel, and that above .50 per cent. in carbon, stand many times longer than soft steel, and that the softer the steel the shorter the life of the rod.

The same thing holds true with everything in steel that has to withstand severe vibratory shocks and strains.

It would seem that the Ordnance Departments of our Army and Navy were doing the correct thing in copying the best practice on the other side, until from our own experience we can make an improvement on it, which I have no doubt will come in a very short time. I don't suppose it is a fact (as Mr. Dorsey's paper would seem to imply), in fact I know it is not, that the ordnance officers are going

ahead in the manufacture of heavy steel guns without thoroughly testing in every possible way the material while under process of manufacture, and the guns themselves at the proving ground when finished.

One thing has not to my knowledge been proved, as yet, and that is that the high ductility that is asked for in hard gun steel is at all necessary. If this should prove not to be the case, then I see no reason why as good, if not a better gun, cannot be made by some modification of the Rodman process applied to a steel cast gun. There is certainly no trouble in reaching a tensile strength of 100,000 pounds per square inch. The experiment of making and trying such a gun would be quite inexpensive, and would seem to be well worth trial by the Ordnance Departments.

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Lieutenant R. R. INGERSOLL, *Head of Department of Ordnance and Gunnery, U. S. N. A.—Mr. Chairman and Gentlemen*:—The paper on "Steel for Heavy Guns" we have heard read, if I correctly understand its meaning, makes very radical assertions. We learn from it that gunmakers, both in this country and abroad, are now pursuing, and have for years been pursuing, a mistaken course in regard to the grade of steel which they consider necessary to use in gun construction.

We are told that the steel demanded by experts in ordnance is an unsafe, unreliable, and treacherous metal by nature, and that to this capricious character of the steel all of the failures of steel guns are directly chargeable. I submit that, if true, this is a lamentable condition of things, and is of vital importance to every one who is interested in the work of the rearmament of our Navy and coast defenses. If true, it means simply this—that all the study, experience and experiments of the past years, by men whose education and life-work have fitted them especially for that duty, have tended to confirm a mistake, and that the whole work of investigation should be commenced anew. Are we prepared to accept such a conclusion? We have heard from time to time criticisms on this or that feature of gun construction—generally by some advocate of a new gun—or of cheap material such as cast iron, or of casting guns on the Rodman principle, etc., etc., but this paper seems to be the first public criticism of the general quality of the steel which ordnance experts deem necessary for their purpose. It must be said, also, that a numerous

class would be glad to see the standard of specifications for gun steel reduced for other than the very worthy motive of the lecturer, which seems to be a conviction that the steel now required is, while nominally a stronger and better metal, in reality a weaker metal for guns than a grade of steel which he proposes. He tells us that if the mild steel, which he defines, is used, we shall always have safe, reliable and strong guns—stronger in reality, though built of steel of less tensile strength than is now the practice wherever steel guns are built. It is to be hoped that a discussion of the subject will be given us from the standpoint of the expert in the manufacture and use of steel in large masses, such as are necessary for guns. Certainly some of our manufacturers ought to be able to tell us whether or not the steel which they have furnished of a tensile strength of 90,000 pounds and upwards is the unsafe and treacherous metal, as stated by the lecturer, and whether steel of 60,000 pounds tensile strength in large masses is always the safe, reliable metal it is declared to be.

It occurs to me that perhaps the difference of opinion, between the lecturer on the one hand, and ordnance officers on the other, as to what is the proper metal to use for guns, may be due to the different standpoints from which these two classes of professional men view the subject. We must defer to the high authority of the opinions of civil and mechanical engineers on the use of a proper metal for machines, bridges, boilers and other structures which come within the limits of their professions and experience; and while a gun may be perhaps called a machine to do certain work, yet it appears from this paper that the able lecturer has not exhausted the subject of the construction and working of this particular machine, a steel gun, the strains upon which differ in character from that of every other mechanical structure, and which in gun construction necessitate the taking into account of very many other matters besides the one fact that the steel shall have a fixed *tensile strength.* This leads to the belief that it perhaps may be shown that the lecturer is mistaken in his view of the matter.

Before attempting to show wherein he is mistaken, as viewed from the standpoint of ordnance officers, it may be proper to say that it seems a very broad and radical statement to make, that because a failure has happened here and there, out of a very large number of trials, that on that account the whole should be condemned; and, in this connection, I have been very much struck with the remarks of Mr. William Kent, mechanical engineer, of New York, on "The

exceptional failures, and but little concerning the thousand successful results.

Now let us consider a few points a little more in detail. The lecturer defines gun steel by its quality of *tensile strength* alone, but he says nothing about the other qualities, which are of much greater importance to gunmakers; and it cannot be accepted as a fact, that the other qualities bear a constant ratio to the *tensile strength*, which the lecturer seems to consider of first importance. In designing bridges, machines and boilers, the *tensile strength*, combined with an assumed factor of safety, limits the load the structure is calculated to stand, and this one quality is always kept in view. With gunmakers, however, the tensile strength is not considered at all in the design of a gun, but the elastic strength and the ductility—or elasticity, if you please—of the metal within its elastic limit. Therefore the *elastic strength*, or the ability of a gun to resist permanent deformation, and *not* its *tensile strength*, or its ability to resist fracture, is the quantity which limits the safe load with any assumed factor of safety. The ratio of the *elastic strength* of a metal to the *tensile strength* may vary from .4 for steel of 55,000 pounds tensile strength to .6 with steel of 130,000 to 150,000 pounds tensile strength. The ductility, or percentage of elongation after fracture, may vary from twenty-seven per cent. with the former, to sixteen to eighteen per cent. with the latter. Again, these ratios vary with steel of the *same* tensile strength, depending upon the manner of treatment and amount of work done on the metal after casting. It is as plain as possible, that simply giving the *tensile strength* of a metal really tells very little about its fitness for gun construction.

The reason we use the elastic strength of a metal in designing guns is obvious to those who have to use the guns. The strains to which a gun is subjected are not simple rending strains, but are vibratory in character. We work within the elastic limit always, and, moreover, seek a metal which has a large percentage of *elastic elongation*, or elongation within the elastic limit, which characteristic aids the metal to resist the vibratory strains to which it is subjected. If the bore of a gun is permanently deformed an appreciable amount by firing, the results would be a loss of velocity and perhaps insufficient rotation of the projectile, causing a loss in range and inaccuracy of flight. Again, the parts of a gun are assembled with a definite shrinkage, and so put together that when a certain powder pressure acts, all the parts will pull, at their interior surfaces, at the elastic limit of each. This

gun could be built, the *elastic strength* would be 1.4 times the elastic strength of the metal, or 1.4 times 30,000 pounds, or about 18.7 tons. So we see that any possible construction will give a strength between 14.7 tons and 18.7 tons, and I submit that the factor of safety with any such gun would be entirely too small, especially in view of the contingency of a premature explosion of a shell in the bore—an event not unlikely, and which would leave its mark in no slight manner on a gun of such low *elastic strength*. Gunmakers are already committed to the plan of very thin hoops for the outer layers, as is exemplified in the case of wire-wound and ribbon-wound guns; but the steel in the form of wire or ribbon has a very high elastic strength. There are certain mechanical difficulties, such as tight joints, soldering, etc., in the way of its use at present, but the moment these difficulties are overcome—and they will be overcome in time—the pressure on the gun will be increased fifty per cent. above what it is now, and the *low-tensile-strength* steel of the lecturer will be more than ever inadmissible for our purpose.

But he says, "If thick hoops must be used, make them thicker of the low steel." This proposition will not do for the Navy, at least; it means increased weight, gun for gun, or a less number of guns to a ship of given tonnage, than is now able to be carried. It means a decrease of our fighting power for a given expenditure of money in ships, coal, equipments, and pay of officers and men. The tendency should, in the opinion of naval men, be rather in the other direction, if possible—lighter guns of the same or greater power, and more of them. Aside from this, it can be shown, without a shadow of doubt, that beyond a certain limit the strength of a gun is not increased materially by adding to the thickness of its walls, since the power to resist internal pressure does not increase proportionally to the thickness.

The lecturer says nothing whatever in regard to the effect of *annealing* on large masses of steel. I presume he will not deny that its effect is most beneficial in producing that uniformity of molecular construction which is desired, and in getting rid of the internal tensions that may exist in the mass, before the steel is subjected to that process, and to which is attributed the unreliability of steel of high grade. He questions the effect of oil-temper on steel in large masses such as are used for guns, and, on this point, such experiments as have been made go to show that its effect is undoubtedly felt throughout the mass. I merely wish to quote one experiment. You will find a

record of it in the report of Captain Rogers Birnie, Ordnance Corps, United States Army, to the Chief of Ordnance, published in a "Note on the Construction of Ordnance," No. 32. In that report a tabulated statement is given of the tests of specimens taken from two cylinders made by Whitworth, of forged, oil-tempered and annealed steel of the quality demanded for the construction of an 8-inch steel gun, and of cross-sections corresponding to those of the tube and jacket of such a gun. The cylinders were twenty-four inches long, and specimen rings were cut out near the middle of the length of the forgings; from these rings test pieces were taken—not near the circumference alone, but some near the centre of the thickness, and others radial. The specimens were tested at the Watertown Arsenal, and an inspection of the tabulated report fails to show any material difference in the metal throughout the thickness. The effect of the oil-temper or process of working this steel after casting was, in this case at least, more than "skin-deep."

In the absence of any practical experience in this country at the commencement of steel-gun construction, who would be most able to give opinions as to the proper steel to use and the best form in which to use it, foreign gunmakers, who have had years of experience, and who have invested immense sums in that industry, or professional men in this country, however able, who have had no experience whatever, who have not a dollar at stake, and who do not risk professional reputation, even if their ideas should not prove successful?

It would seem that the best interests of the Government, and of the public, lie in a high standard of tests, and that with the constant improvement in the quality of steel produced, and with the gain in the knowledge of that metal, the standard will probably grow higher rather than lower.

What we want with gun steel is uniformity; but this should be a development with high rather than with low qualities, and the tendency and march of events indicate that this will be attained by, 1st, a more intimate chemical knowledge of steel; 2d, a less barbarous forging machine than the hammer; 3d, annealing; 4th, oil-tempering.

It seems to me, gentlemen, that we have gotten beyond the experimental stage, with the smaller calibres of naval guns, at least, in this country, and what more could be learned by a new set of experiments with guns built of the steel proposed by the lecturer, is not evident, unless, perhaps, that it would be shown, beyond a doubt, to that gentleman and those who support his views, that a gun so constructed

would not suffice for the work we require. That fact is known already, however, so far as the interests of the Government are concerned, without the expense and delay of experiments.

The guns, as now built, have stood every reasonable test that may be demanded of them, the problem of what kind of steel it is best to use has been solved to the satisfaction of those who will have to use the guns, and all we ask, in the event of war, is to be allowed the privilege of defending our flag with just such guns as are now being made.

Lieutenant-Commander F. M. BARBER.—*Mr. Chairman and Gentlemen*:—The essay before us comes at a most opportune time in the history of modern gun fabrication in the United States, because it probably represents, in a general way, not only the ideas of most manufacturers of steel in the United States, but of citizens generally, except such as are interested in cast iron or unforged cast steel.

From the nature of his treatment of the subject, it is difficult to criticise the article as a whole, because the author does not go sufficiently into details for one to be always sure of what he really means, and it is not fair to assume that he means one thing when he might mean another.

It seems, therefore, better to merely point out in a general way and at some length what appear to be doubtful or debatable points that strike one in reading over the article; such points as in my opinion would tend seriously to vitiate the argument of the essayist.

First and foremost, there is no mention whatever throughout the entire article of the *elastic limit* of the metal, or of the process of *annealing*.

To the ordnance expert, this absolutely ruins the whole argument of the essayist; but, as it is to be hoped that, for the benefit of the service, the article and its criticisms will receive a wider circulation than among our officers, it is necessary to proceed more at length.

The elastic limit, and not the rupturing limit, marks the boundary of the artillerist's working range, because it means to him the power of the metal to endure vibrations and still return to its original form. It contains the only valuable part of the power of elongation of the metal, so far as he is concerned, and the more of this elongation he has within his limit, the better he is pleased. The ductility or stretch outside of his limit he cares little about. The better the steel, the higher the elastic limit, the more of this elongation within it in

proportion to the total elongation, and consequently the wider the artillerist's range.

The rupturing limit only means the capacity of the metal to endure loads, and perhaps undulations, as in a bridge; but most civil engineers, now-a-days, are of the opinion that even when steel is used for ordinary commercial structural purposes, working loads should be determined with reference to the elastic limit.

Roughly speaking, the elastic limit is about half the rupturing strain, and, therefore, with the steel of 60,000 pounds per square inch tensile strength, the elastic limit would be a little more than 30,000 pounds; this is somewhat less than the pressure in the powder chamber of the 6-inch or 8-inch guns, which have been safely through the statutory test at Annapolis, and which would have been permanently deformed and ruined if made of the steel in question.

With the steel advocated by the essayist there is practically no elastic limit to work on, bearing in mind what has been said about the amount of elongation inside the elastic limit in proportion to what is beyond it, and also bearing in mind what pressures we must consider. Krupp states (see *Army and Navy Register* of December 18th) that a pressure of 18.76 to 19.52 tons per square inch *is not excessive* for his 118-ton guns.

This can best be illustrated by an example or comparison of the results obtained on the same sized test specimen, two inches long and one-half inch in diameter, by a Midvale oil-tempered and annealed six-inch gun hoop and a Chester Rolling Mills low steel plate as near like what the essayist advocates as possible—a little better, perhaps:

| Steel. | Tensile Strength. | Elastic Limit. | Total Elongation. | Elong. Inside of Elastic Limit. |
|---|---|---|---|---|
| Midvale...... | 105,000 lbs. | 60,000 | 19 per cent. | .2 per cent. |
| Chester....... | 60,000 lbs. | 31,000 | 34 per cent.* | .1 per cent. |

Observe the difference in the elastic ratio, and also in the amount of elongation available to the gunmaker. Of course this elastic ratio in the low steel can be raised by "fooling" with the phosphorus and making it higher, but that will make a good test specimen and won't make anything else; the plate will not work or reheat many times.

The elastic limit of the steel of the essayist cannot be increased legitimately, except possibly to a slight degree, by working it, because the metal contains very little carbon and will not temper. The elastic

*This would be about 25 per cent. on an 8-inch test piece.

: of the gun is increased very matecially in building up, but this ies as well to the higher grade of steel as to the lower.

he paragraph commencing "All workers in steel will admit," etc., is excellent, except, perhaps, the remark about the zero of :hery being at 60,000 pounds tensile strength. *All* steel is treach-ıs to those who do not understand it, whether its tensile strength ›,000, 60,000 or 160,000 pounds.

he statement that mild steel is the most reliable of all cheap ıls, and that it can be *badly worked and maltreated with impunity*, not been borne out in naval experience. There probably never as good, and certainly never any better, steel put into vessels ı in the Atlanta, Boston, etc. This steel was obliged to show oo pounds tensile, and 23 per cent. elongation, as an average on test pieces, for hull material; and for boilers the four test pieces d show a variation of from 63,000 to 57,000, but the average must t least 60,000, and the elongation 25 per cent.; these results to be ined on a test specimen measuring eight inches between reference ıts. The French Navy requirements are greater than these; the lish Navy demands are less.

he reports of the Advisory Board on this material are used as ertisements to-day by all the people that produced the metal; yet, d as it was (much better than Lloyd's Registry demands), it had ›e carefully handled and never abused. To bend the end of a c beam, for example, always required skill and care; it had to be ıed round a corner, so to speak, and if improperly treated, like ding it at a black heat, or overheating, it would break. Tube :ts also sometimes gave trouble;* but the total number of failures very small, because care *was* exercised, and the men were skilled. s material, *intelligently* treated, would do anything that ship and er construction required of it.

he essayist persists in referring to gun steel as HARD steel, and he up an arbitrary definition of hard steel in which he places the ile strength at the rather low figure of 90,000, and specifies neither elongation, nor elastic limit, nor contraction of area. He appears hink, also, that the tube, jacket and hoops are all made of steel the same physical characteristics. The *untempered* steel that

[n the new circular of tests for steel for cruisers, issued by the Navy De-ment December 16, 1886, all flanging plates are required to be between ›o and 55,000 pounds in tensile strength, with not less than 29 per cent. gation in 8 inches.

would make the army ordnance hoop that he refers to would probably record forty tons tensile, upward of twenty tons elastic limit, and twenty per cent. elongation. It is simply splendid steel which will take the skilful treatment that will make it still better.

The tube and jacket of that gun would probably demand less tensile strength, lower elastic limit, and greater elongation.

The remarks on oil-temper are not warranted by a thorough knowledge of what good practice is daily producing. If the failure of guns to which the essayist refers proves anything, it proves that the metal was not annealed. Indeed, in the most notable of recent failures, that of the Collingwood gun, the specially appointed commission, in their report of August, 1886, particularly state that one of the causes was "the absence of annealing after forging, and oil-hardening, which treatment would have mitigated any internal strains set up by these processes"; and they say never a word against oil-temper. They concluded by recommending an oil-tempered and annealed material more difficult of realization than our army ordnance hoop, and it would be difficult for the essayist to produce a more competent set of judges anywhere than this ordnance committee and its specially associated members.

Midvale and Cambria in the United States, Creuzot in France, Whitworth in England, and Krupp in Germany, would all differ from the essayist in the idea that the failures of modern guns are largely due to defective oil-temper; they would smile, too, at the idea that Lloyd's had more practical knowledge of steel than they, especially when one compares gun steel with boiler steel, and considers the fact that the experience of these firms extends more or less to both kinds of steel, while Lloyd's is confined to boilers and ship material.

Not only are a boiler and a gun subjected to different kinds of pressure, but the 100 to 200 pounds of the one bears no comparison with the fifteen tons of the other, making all due allowance for the stronger and more compact shape of the gun. It is not surprising, then, that the specifications for a gun should be double what they are for a boiler.

The essayist does not mention the dimensions of the test piece on which his metal is to show 55,000 to 60,000 pounds, and on which its elongation is to be measured. Nothing in steel work leads to more erroneous conclusions as regards the quality of the metal one is dealing with. The 60,000 pounds tensile demanded by the U. S. Navy Department for ship plate, on its standard test

piece, required (as shown by actual experiment at Park Bros.' in Pittsburgh) over 70,000 on the commercial test piece, which was thinner and had less length of uniform section exposed to the strain. Again, American, English and French ordnance test pieces are round, and vary from .5 to .56 square inch in cross-section. In these pieces differences of length (within reasonable limits) have very little effect on the tensile strength; but the elongation is less in percent. as the test piece is longer.

By the reasoning of the essayist from Lloyd's, if the proportion were extended as he extends it, the above-mentioned army ordnance hoop would have a tensile strength of only 50,000, and an elastic limit of a little over 25,000 pounds, or say ten tons, and the walls of a 16-inch gun would give a *minus* tensile strength of over 20,000 pounds on the outer layer. Of what value is such reasoning as that, as applied to guns? Lloyd's Registry is not the best standard in the world even for ships. Their latest rules for ship plate require a tensile strength of twenty-seven to thirty tons, and an elongation of only sixteen per cent. on a length of eight inches; the same test piece that the essayist refers to. That is hard steel in more senses than one, and we would not put it into anything. It is possible to suppose that in England the pressure of commercial enterprise has succeeded in lowering the standard, instead of the general interest of the community and the safety of "those who go down to the sea in ships" having due weight with the Government in keeping the standard up.

To the statement of the Duke of Cambridge regarding the failure of the Krupp guns around Paris, the essayist might have added that, during the campaign of the Loire, twenty-four guns of Prince Frederick Charles were also disabled by their own fire; but this is no proof that the guns burst, as the essay insinuates. Similar statements were made last year regarding the De Bange guns.

As a matter of fact, the number of modern steel guns that have burst in proportion to the number that have not burst is exceedingly small; without doubt it is a very much more favorable showing than steam boilers could make.

The failure of guns "from the effect of their own fire" usually means some defect in the gun construction which has *temporarily* disabled them. It may have put them *hors de combat* forever, but they did not necessarily burst. A failure or sticking of the gas check, or a derangement of the breech mechanism, or damage to it

from prematurely firing the gun, are the most probable; more serious defects than these are slipping of the tube, erosion of the chamber, etc., etc. To all of these, except, perhaps, the very last, the essayist's metal would be still more liable than gun steel, on account of the facility with which it can be permanently deformed.

There is no *if* about the necessity or desirability of light guns for the Navy, where the total ordnance outfit of a vessel is limited to about six per cent. of her displacement. The lightness of our guns should only be limited by our power to control the recoil without tearing everything to pieces about the carriage or ship's side.

There is a mechanical difficulty about turning very thin hoops: they spring to the tool. The thin-hoop system carried to its logical conclusion is the wire-wound gun, and the elastic limit of Dr. Woodbridge's wire is 100,000 pounds.

In conclusion, it may be said that since the metal of the essayist will melt and cast and forge and roll, it possesses an advantage in facility of manufacture over wrought iron for gunmaking; but all these advantages are obtained by the introduction of carbon, and it may almost be said that the good qualities of the metal are in proportion to the carbon; but treachery is introduced at the same time, and different methods must be resorted to according to circumstances to overcome the difficulty.

When the quantity of carbon is very small, say from .10 to .14 per cent., as in the essayist's metal, the treachery can be reduced to small proportions by careful attention to the other chemical constituents, and by careful working of the ingot and shaped articles at the proper temperature and to a sufficient extent; but this is all that can be done, and the metal will still lack the essential qualities of high elastic limit, great elongation within this limit, and high tenacity, which are so necessary in modern gun metal.

These qualities can only be obtained at the present day by the use of the very best ores, more carefully selected than before, and by the introduction of .4 to .6 per cent. of carbon. The treachery here cannot be overcome by simple working; but it can be overcome, and it *is* overcome, by oil-tempering and annealing at proper stages of the fabrication. Any gun steel, however, costs money.

The essayist asserts that his steel can be had all over the country for $60 per ton. There is little doubt of it, so far as thin plate is concerned; but the metal of the Atlanta, Boston and Chicago cost nearer $100 per ton; and neither figure affords any idea of what the essayist's

metal would cost, if he attempted to produce it in the huge masses necessary for the enormous guns of the present day. The idea that it could be had for $60 per ton, as he appears to think, is entirely fallacious. Let him put his figure at $700 to $800 per ton, and he will not be far off from what it will cost him, or any one else, to make steel guns in the United States that will compare with those that foreigners would bring against us.

It appears, then, that the principal objection to the metal proposed by the essayist is that feature for which he deems it most desirable—viz.: that it will not temper. He has introduced the treacherous element without introducing enough of it to make the metal susceptible to the only treatment that enables us to overcome the treachery and bring out those high qualities which are essential to modern guns. At the same time he asserts without proof that this treatment is unreliable and unsatisfactory when applied to large masses, as though this were an additional argument for the use of his metal, which is too poor to be brought up to our standard by any treatment that we know of.

Suppose now we could get this metal in sufficiently large masses and of uniform quality, and were *forced* by the necessities of war to-morrow to use it because we had no other, and fired the gun with powder limited in strength to the capacity of the metal; the weight and size of the gun would make it directly the opposite of what is wanted on board ship, where our great aim is to have as light, handy guns as possible, and as heavy ammunition as possible. We have already reached a point where a hundred rounds of ammunition weigh as much as the gun and carriage, and we hope to do even better.

For land service, the ultimate weight of the body of this gun (of any calibre) would be reached when the process of adding metal to the exterior ceased to give additional strength to the interior—viz.: when one could stretch the bore out of all shape and not know it from the appearance of the outside of the gun. It is not merely a question of adding metal to the outside of the gun till it reaches infinity with *any* system of building up, nor of working the metal indefinitely, because it is possible to work it too much. All the properties that can be put into a gun by building up are thoroughly understood, whatever be the metal, and the experiments that he recommends are not necessary. The ultimate weight added to the gun by increasing its length would depend on the amount of weak, slow-

The study o structural or bridge steel will not give a correct knowledge of what is suitable for the special purpose of ordnance. The methods of manufacture of bridge steel and ordnance steel are not the same and cannot be so. A bar of bridge steel, say six inches by one inch section, is rolled from an ingot, say from sixteen inches by eighteen inches or fourteen inches by fourteen inches square section extended thirty to fifty times. All crystals, and with them all blow-holes and imperfections, are extended longitudinally thirty to fifty times their original length, and reduced in area from one-thirtieth to one-fiftieth of their original cross-section. The resulting material, if of low carbon, is approximately fibrous, and, made in many cases from ingots originally full of blow-holes, is full of small longitudinal seams of no practical disadvantage in the application to tensile work. Such a material as this was thoroughly tried by the British in their Fraser guns, where the hoops, made of a long wrought-iron bar wound in a coil and welded, were a soft, fibrous material of low elastic limit, such as Mr. Dorsey describes, and these soft coils were shrunk on soft steel tubes. When such material was finally abandoned by the English ordnance officers, under the pressure of the absolute proof that their artillery was inferior to the German and French, they then took up the use of modern ordnance steel and practically acknowledged their previous practice was a mistake. Several of such guns burst, the gun of the Thunderer being one, and another a six-inch at Shoeburyness, with an iron jacket, burst into ten pieces of tube and sixteen pieces of jacket.

How can such treatment as gives us fibre be applied to modern gun material, and is such treatment desirable? The axial extension of gun material and great development of longitudinal fibre will not increase the value of the material to resist tangential or compressive strains while the longitudinal strains in a gun are not comparatively large. If jackets and tubes are manufactured by punching or boring a hole in the ingot and then dilating it, the utmost extension possible in the tangential direction is but two or three times the original length. Those entering this branch of manufacture will find that if there is not absolute solidity in the ingot, no amount of work will give a gun forging that will pass United States Government inspection. A soft steel will not be easier to make solid, and cannot be more cheaply made, if made good. Disseminated blow-holes are fatal to the standard of excellence our officers demand. Mr. Dorsey is in

error in many particulars; for instance, he makes a slight error in saying that mild steel is incapable of taking temper. The ultimate strength and elastic limit of the 60,000 pounds steel may be considerably affected by variations of treatment and consequent variations of crystalline condition, as practical manufacturers of structural steel have found out. We have carefully investigated this fact. Again, he speaks of capriciousness and treacherousness of steel. For this I think we should read ignorance of users. Manufacturers have treated steel as they would wrought iron, in ignorance of the very marked effect upon the characteristics of steel produced by improper treatment.

As an extensively used structural material steel has not been handled for over ten years, either in bridge or guns; but there are manufacturers that by the lessons received in the school of experience know something of its qualities and are learning more all the time. For half a century we have had discussions as to the possibility of crystallization of iron by vibration in use. It is even now a mooted point whether or not a car-axle, for instance, originally of good fibrous material, can become coarse and crystalline in use. If fifty years of experience will not settle all points in the manufacture of iron, can we expect to know steel in ten? We have to-day, and every day, broken car-axles, steel or iron, broken steel rails, one, perhaps, where there used to be one hundred broken iron ones, and breaks and accidents everywhere in machinery in the management of careful and studious engineers. Still in civil life, where the safety of thousands depends upon our judgment, we do not say, "This steel is a treacherous material; let us go back to iron rails and iron tires and axles, and use no more steel." We do say, very properly, "Here are some laws not fully known to us. We cannot afford to drop this cheap and excellent material, but must find out its unknown qualities and use it with greater intelligence." As for the treacherous qualities of steel being zero at 60,000 ultimate, a little experience with plenty of phosphorus will show it capricious at 60,000 pounds ultimate. Nor does the treacherousness of steel necessarily increase with its size, etc. Size has this influence in the manufacture of a material made often in old plants, with machinery too light to put suitable work upon its product, that there is a greater temptation to turn out large bars with too little work. The variation in treatment of large pieces is apt to be greater than in manufacturing small pieces, and hence the variation of result. Nor do the tensile strength and

elastic limit vary, the work being the same if the treatment is the same for the large as for the small pieces. The working temperature, cooling contact of rolls, and possible mechanical differences of treatment, have a great influence upon the character of steel, not afterwards treated, to correct its crystalline condition.

We have heard a great deal about gun failures, and may say that newspaper gossip is generally not sufficiently accurate to supply working data for engineers. I should like some one of the members of this Institute who has seen the official reports, if there are such, to tell us what guns failed. Does not much of this gossip refer to the old Fraser gun, not now held to be a good construction? How many modern steel guns have failed in England, what sizes were they, and in what parts did they fail? And to what tests had the failing pieces been subjected, to ascertain whether they were suitable to put in a gun? If I am not misinformed, there was gross carelessness displayed by the English ordnance officers in this particular of inspection of quality. In this respect they are far behind the French.

An English ordnance board, after the Collingwood explosion, reported that the tube was irregular in quality, and absurdly recommended that test-pieces should be cut out of the tubes submitted, tempered and tested. The ignorance that would take such a test as a measure of the excellence of the tube would do anything.

As to the remarks of the Duke of Cambridge in 1876, it may be he was trying to prove that the English artillery, since then abandoned, was the finest in the world, and, to do so, endeavored to damage the reputation of the Krupp guns, made on another system. Who knows what are the details of these failures he speaks of? There are a thousand minor accidents liable to happen to a siege-gun in the field, to disable it or its carriage; and very possibly a proportion of the thirty-six accidents were such, and were not such accidents involving bursting of tube or jacket. An argument against steel guns supported by no more evidence than such a crude statement made in parliamentary debate is not an engineering argument. Besides, since the date of this statement, ten years ago, referring to guns of probably fifteen years since, much more is known of steel.

As to oil-tempering, the author's remarks may be taken as an expression of opinion from one somewhat uninformed on the subject. Much of the information of this kind is in the hands of a few manufacturers, and is in the nature of special trade skill, not laid open to the general public. Krupp does not make public his methods; nor

do the Creuzot or St. Chamond works in France. All, however, treat their steel in an oil-bath. Few armor-plates of steel would be reliable if untreated. There are manufacturers in this country who know the effects of oil-tempering. They have gained their information in costly experiments, long continued and carefully carried out. It is sufficient to say that no one is likely to reach our present ordnance requirements with untreated steel. When an expert can treat a gun forging to come within three thousand pounds of the desired mark, in a steel which can be made to range in elastic from 40,000 to 80,000, and in ultimate from 90,000 to 130,000, his methods cannot be called unreliable, or the results inconclusive. There are many hundreds of tests which have been made upon tempered steel which will prove the results of tempering very conclusively. That hard steel is a compact substance, is in favor of the rapid cooling effect of an oil-bath and not against it, while the ordnance tests show the cooling effect will penetrate to the centre of the largest gun hoops, with very trifling differences in hardness between the interior and an outside corner. No piece can be more favorably shaped for heating equally and for rapid and effective cooling than a hollow cylinder, such as a gun-tube, jacket or hoop, especially if treated with an inside circulation, as in recent French methods. No shape can be heated and cooled with less risk of damage to it.

Bridge engineers, instead of ignoring the effects of tempering, would do well to study the subject, for I believe much material is used in bridges that is faulty in condition, and which can be corrected by proper treatment.

It may perhaps interest the Institute to know that there is a concern (the Cambria Company) manufacturing railway axles, a steel product required to stand continuous and severe shocks, that, after study of the best method of making them of uniform condition, has adopted the method of tempering and annealing. And here let me say that this should be called toughening, because steel in which the particles are caught in the proper state and fixed by sudden cooling while they are in this state, is really in the strongest possible condition. It is toughened, and the after annealing will serve to make it as soft as it can possibly be consistent with its analysis. If a concern with reputation to maintain, and with a product to sell for which its reputation is a guarantee, deliberately adopts the method of tempering at increased cost, of finishing that product, this fact says something for the method; and if that process is applied to an amount of steel

production equal in weight to a sixteen-inch steel gun, every week, this also says something for the method. We have proved our ground by experiments which showed the great superiority of the treated axle.

The remarks of the Lloyd's specifications, to my mind, is another misinterpretation of facts. As commercially manufactured, large and small material, thick and thin plates, are made from the same sized ingots or blooms, and the larger bars and thickest plates are very apt to be worked at higher temperature than small bars or thin plates. Hence the same material will show lower elastic limits and ultimate strength in thick pieces. Lloyd's, unable to revolutionize manufacture, provided for this difference, in order that the manufacturer should not increase the carbon in the thick plates to attain the higher ultimate of the lower-carbon, colder-rolled, thin plates.

To meet the point of the damages to steel guns from shot striking them, I will cite the following experiment as a case in point, to show the effect of punishment on gun steel: A rejected ring of which we desired to have a fracture on a large scale was placed under our drop. The ring was twenty inches by four inches section, about thirty inches diameter, and the weight was a new conical-pointed air-furnace cast-iron ball, 4600 pounds, falling forty-six feet. Our drop hands are experts at breaking material up, and placed the ring as favorably as possible. No accurate record was kept, as all we were after was a specimen fracture. After thirty or forty blows from full height of drop, which only resulted in knocking the ring about one-half inch elliptical, we gave the contest up. There was no discoverable crack or break in the hoop, and I have no hesitation in expressing my belief that you might plaster machine-gun shot all over a good steel gun without damage beyond the superficial marks or cuts the bullets would make. Upon this point I would like to hear from some of the ordnance officers.

As to commercial use, hard steel, if this gun material may be called hard steel, is not unknown nor inextensively used. The use of steel tire on the wheels of every locomotive and nearly every first-class passenger car in this land or abroad is well known. The carbon or hardness of tire steel is not less than approved gun steel. We risk our lives upon the safety of such steel every day, and might be willing to risk the lives of our paid military men upon a much more carefully made and selected quality of no harder steel. Rails thirty to forty carbon, axles thirty carbon, and many other things, are by no

means of mild steel. Nor has the experimental use of soft steel for rails proved it safer than higher carbons.

Finally, let us touch the vital point. The author says a gun can be made of low steel. He does not submit a design for such a gun properly proportioned, and until he does submit a design that will stand intelligent criticism, I hardly think he is entitled to a hearing on that side of the case. For reasons well known to even the superficial student of the strains in modern guns, no low-steel gun can be designed to stand high-powder pressure. Unless we abandon the high pressure and the high velocity of the modern steel guns, and with these the low trajectory, great range and penetrative power of these pieces, we must use high steel. Reducing the ultimate strength of steel in tubes and jackets means reducing the amount of compression they will stand with guns at rest, and a similar loss of tensile strength with guns in action, so that this loss of strength acts at both extremes and is a double loss.

As for the hoop system farthest removed from the shocks and subject to the least extension, it would be bad engineering to use a material of less elastic and ultimate, and more ductile, than that in the tubes and jacket. Every system that does this will come to grief.

So far as the hoop system of the guns goes, I can speak from knowledge of my own great confidence in the excellence of the material and in the care of its selection by our officers. I have been unable to find, and doubt if any authenticated case of burst steel hoops exists, sufficient to alarm an engineer of good judgment. Let us carry into this matter a little of the common sense we apply to every-day engineering. This is a question of maximum offensive power against our enemies, and it may even pay to risk the bursting of a gun, if, in doing so, we punch a hole in the enemy's armor and sink his ship. It is a question of effect and its cost.

Our naval vessels must carry artillery giving the maximum penetration and offensive power for the given weight. War is not a safe business, even at the butt-end of a gun, and with good engineering work, done with good judgment, it is the duty of our artillerymen to do the most damage possible to our enemy, taking in warfare at least as much risk as to the strength of structures they use as a good engineer in civil life does with his locomotives and bridges.

Mr. R. W. DAVENPORT, *Superintendent of the Midvale Steel Co., Philadelphia, Pa.—Mr. Chairman and Gentlemen:*—Being very

much interested in the subject now before the Institute, and having been closely connected, in my work at Midvale, with the first efforts looking to the manufacture of steel for heavy guns in this country, I have read with much care Mr. Dorsey's paper, and would like to make a few remarks on the subject from a manufacturing standpoint.

We have all heard with interest the able papers of the gentlemen, representing both the Navy and the Army, who have given the subject of gun construction much study, and no one can doubt but that their conclusions are correct, and that they know what they want, and that if they can obtain a metal for their guns possessing all the good qualities they desire, the problem of safe high-power guns will be practically solved.

The question for us steel manufacturers to consider is, can we make a thoroughly reliable metal that will meet the theoretical demands of the gun constructors? And if not, how closely can we approximate to such results? It is from this point of view that I shall take the liberty of criticising some of Mr. Dorsey's statements and conclusions.

In general, I may say that I feel very sure that if Mr. Dorsey had given near as much study to the subject of gun construction and the manufacture of steel for heavy ordnance as he has to bridge construction and the manufacture and use of structural steel, he never would have made several of the statements or drawn the conclusion contained in his paper. In my opinion his paper shows a great lack of thorough investigation of the present state of the art of manufacturing forgings for guns, and contains a number of statements that are, to say the least, misleading.

I make this general statement with a full appreciation of the truth and importance of what is undoubtedly the leading idea of Mr. Dorsey's paper—namely, that in the desire and efforts of our gun constructors to obtain material possessing a very high tensile strength, and especially a high elastic limit, there *is* a danger of using a harder steel than is thoroughly consistent with maximum safety. I do not mean to say that up to the present time this has been done in the guns constructed in this country—I do not think it has—but simply to point out that such a danger does exist, and that beyond doubt hard steel, and especially large masses of hard steel, require more care in working than does very soft steel under similar circumstances. But, because this may be the case, are there any just grounds for discarding entirely all the admirable qualities and possibilities possessed by

term *medium hard steels* (for hard steels, properly so ot used in the construction of ordnance), and, without effort to avoid and overcome the difficulties that may be ie manufacture of such steels, confine ourselves to the le of metal which, on the whole, is so poorly adapted to ion of guns as is the very soft steel which Mr. Dorsey And it is just here that I think that Mr. Dorsey has miss in not thoroughly informing himself of what has being done to take advantage of the high qualities of l steel, while avoiding the dangers that may, under un- :umstances, exist in the manufacture of the same.

:r the paper more in detail, I should like to refer to a ıich appear to me to be especially misleading :

iding steel into two classes—viz.: mild steel having a th of from 55,000 to 65,000 pounds per square inch, and th a tensile strength of over 90,000 pounds—the all-im- lying between these two extremes is entirely overlooked. t is that a very large proportion of the metal used for tion—namely, that from which the heavy forgings for l jackets are made—falls within this intermediate class, tural* tensile strength of from 75,000 to 90,000 pounds ch and an elongation of from 25 to 20 per cent., measured ieters. It is, in most cases, only the hoops forming the rs of the built-up gun that are made of a steel having a e strength of from 90,000 to 100,000 pounds per square elongation of from 20 to 15 per cent., and any one who with the modern theory of gun construction will admit only highly advantageous, but also perfectly consistent o use a harder steel for the exterior hoops than for the and intermediate jacket, which first receive the shock of a of the powder and resist in great part the vibratory d thereby.

iding steel into two classes, soft and hard, Mr. Dorsey has only one property of the metal—namely, its ultimate ten- —and has made no mention of its elastic limit and the : the elastic limit. These are the two properties which

rence is made to the "natural" physical properties of steel, I operties which are shown by the tensile test of a bar rolled or ne square inch, finished at about a cherry heat, with no subse- it.

are most used by the gun constructor in his calculations, and which he desires to have as great as practicable.

Above all, no mention is made of the total elongation and contraction of area at fracture. Now, these are the physical properties which indicate the ability of metal to resist sudden shock and distortion without fracture, and which, of course, exist in the highest degree in very mild or soft steels; but the question as to what extent these properties can, by proper method of manufacture, be combined with a much higher tensile strength and consequent elastic limit than can possibly exist in large masses of the material which Mr. Dorsey advocates, receives no consideration in his paper. If a material could be produced combining the maximum tensile strength of a tempered hard steel with the total elongation of boiler plate, would it not be pre-eminently adapted to all structural purposes? And can it be doubted that it must be the aim of every manufacturer of steel for guns to produce a metal in which these properties—*i. e.* high tensile strength and elastic limit, and great elongation and contraction of area—are combined in the highest possible degree?

As an example of what has been attained under favorable circumstances, may be noted the chase hoops for 8-inch and 10-inch guns, made by the Midvale Steel Company, in which an average of twenty specimens four diameters in length, taken from ten hoops, show an ultimate tensile strength of 100,800 pounds per square inch, an elastic limit of 57,000 pounds, a total elongation of 21.94 per cent., and a contraction of area of 43.58 per cent. Also, in jackets for 6-inch guns, an average of twenty-four specimens, taken from four jackets, show 92,000 pounds per square inch tensile strength, 45,500 elastic limit, 22 per cent. elongation, and 41 per cent. contraction, while an average of twenty specimens taken from four tubes for 6-inch guns show an ultimate tensile strength of 82,000 pounds per square inch, an elastic limit of 42,500 pounds, a total elongation of 24.6 per cent., and a contraction of area of 47.8 per cent. It cannot be doubted that the elongations and contractions above given indicate a metal whose ability to resist shock and distortion is very great, and it would certainly be most unwise not to utilize an elastic limit which in the case of the tubes and jackets is nearly as great as, and in the case of the hoops equal to, the tensile strength of the material which Mr. Dorsey recommends.

3d. As regards the oil-tempering of forgings for guns, Mr. Dorsey's remarks indicate an almost complete lack of knowledge, not only of

the generally accepted theories of how the tempering affects the molecular structure of the steel, but also of the real object of such treatment, of the details of the operation, and of the unquestionable proof of the beneficial effect of the same based on great numbers of carefully made tests.

It is *not* generally supposed that the oil into which a piece of hot steel is immersed permeates the mass, exercising some mysterious influence for good, and it is therefore difficult to see why the "compactness" of the metal need be considered. It is generally admitted that the effect of tempering in oil or any other liquid is to *fix* by rapid cooling the amorphous conditions existing in the heated mass, thus preventing the formation of a coarsely crystalline structure, and destroying the irregular and more or less coarsely crystalline condition existing in every forging of considerable size when it leaves the hammer. Oil is used instead of water simply because it cools less rapidly, and therefore the danger of cracking the piece by internal strains is obviated, and tubes and jackets are tempered after boring in order that the oil may pass up through the bore and cool the walls of the cylinder more rapidly. This tempering or rapid cooling of course hardens the steel and increases the tensile strength and elastic limit while decreasing its elongation and contraction; but in most cases this is not the end in view, or at all events only to a limited extent, and the tempering should always be followed by some process of annealing by which the internal strains are relieved and ultimate tensile strength reduced to the point required. By such treatment the elastic limit, as related to the tensile strength and the elongation at the elastic limit, is decidedly increased throughout the mass, and if the piece has been sufficiently annealed to reduce its tensile strength approximately to that of the steel in its natural condition, the elongation and contraction of area of the metal are largely increased. Beside this, the molecular condition of the mass is far more uniform after treatment than before, and while the effect of the tempering decreases as the thickness of the piece increases, it can be assumed that practically uniform qualities are obtained in cylinders whose walls are four inches thick. In this connection it may be mentioned that the failures of the English guns referred to by Mr. Dorsey are without doubt in great part due to the fact that formerly it was not the custom at Woolwich to thoroughly anneal the tubes, or in fact any of the parts, after tempering, and that therefore the elongation and contraction of area of the metal were so reduced by the hardening process used alone that the tubes in partic-

ular were not in a fit condition to resist the shock and vibratory action of the explosion.

4th. From Mr. Dorsey's statements, persons unfamiliar with existing facts would be led to infer that the harder grades of steel were rather uncommon products and difficult and costly to manufacture; this is very far from being the case. In the first place, the steel of which rails are usually made (and more steel is put into rails than into all other products combined) has a tensile strength of from 70,000 to 80,000 pounds per square inch, and in the best quality of rails, where the phosphorus is low, the carbon often runs as high as .4 per cent., which corresponds to a tensile strength of about 90,000 pounds per square inch. Again, locomotive and car-wheel tires, which are made in large quantities by the open-hearth process, and which, for instance, form the principal product of the Midvale Company, are much harder than rails. Thus, of the four grades of Midvale tire steel, the softest has a natural tensile strength of about 100,000 pounds per square inch, with from fourteen to seventeen per cent. elongation in a length of eight diameters, while the tensile strength of the hardest grade varies from 130,000 to 140,000 pounds, with an elongation of from seven to ten per cent. According to the specifications of the Pennsylvania Railroad, steel for axles should have a tensile strength of 80,000 pounds per square inch, and for crank pins 85,000 pounds, while spring steel, with a tensile strength of about 125,000 pounds per square inch, is regularly produced in large quantities by the open-hearth as well as by the crucible process. Many more instances could be cited, but the above are enough to show that the production of *hard*, as well as *medium hard*, steels on a commercial scale is the rule rather than the exception.

5th. I may finally remark that what Mr. Dorsey says regarding the *economy* to be attained by the use of very soft steel for gun forgings is especially misleading, and shows how little he has considered the real causes of the high cost of material for gun construction; one might infer from his paper that it is only necessary to purchase a lot of soft steel rolled into bars of some convenient shape, at $60 per ton, and therewith construct a gun. In point of fact, there would be little or no difference in the cost of the manufacture of forgings from the very soft steel recommended by Mr. Dorsey, or the medium hard steels from which such forgings are made. The question of the cost of the stock or raw material used need not be considered, for the difference in value between the commoner grades

of raw material and the high grades used for making ingots for gun forgings forms so small a percentage of the total cost of producing such forgings that it would be very unwise to attempt to economize in this direction; especially as, in order to successfully meet the specifications, the *best* material is none too good. The real causes of the high cost of the steel forgings required for gun construction are, first, the large loss of material in forging due to scrapping about fifty per cent. of the original weight of the ingot in order to make use of only the best part of same; second, the amount of machine-work required to rough-bore and turn the forgings, and the great loss of weight due to these operations; third, the cost of oil-tempering and annealing; fourth, the extra metal that must be allowed in the length of the forgings for testing, all of which ultimately goes to waste, and the cost of cutting out and preparing test specimens. This expense of testing amounts to much more than would be supposed. Fifth, the rejections due to material not fully meeting the specifications, or to the presence of slight defects, which may only be discovered when the piece is being finished, after provisional acceptance. Now, all the above items of cost would be practically the same, whether a very soft or a medium hard grade of steel be used. In some respects, indeed, as in the operations of melting and casting, where, to make large ingots, the products of several furnaces have to be combined, the costs and risks of production are less in the case of the harder than of the softer steel, while the expense of doing the machine-work on the former would be somewhat greater than on the latter. When, however, it is remembered that, in order to construct a gun of equal strength, a greater weight of the softer than of the harder steel would be required, it is evident that, instead of there being any economy in following Mr. Dorsey's recommendations, there would be a considerable increase of cost. I have only to add that I hope the above remarks, made from a manufacturer's point of view, may help to prove that Mr. Dorsey's attack on the best modern practice in gun construction is entirely unwarranted, and that his data, as well as his conclusions, are unscientific.

Mr. ISAAC G. JOHNSON, *Proprietor Crucible-Cast-Steel Works, Spuyten Duyvil, New York.—Mr. Chairman and Gentlemen* :—In considering the paper from Mr. Dorsey that has just been read, I notice that he treats steel as being of two grades, which he calls "mild" steel, having a tensile strength of 55,000 pounds to the square

inch, and "high-tool" steel, having a tensile strength of 150,000 pounds.

I would call your attention to the fact that steel, instead of being a simple metal, is an alloy, composed not only of metallic elements, but of non-metallic. It is also found to be an alloy of extreme sensitiveness. Its character is determined not only by the elements entering into it, but by the various proportions of those elements, the quality changing as the proportion of the different elements changes. We find in practice that the introduction of a new element in almost homeopathic quantities materially affects the quality of steel.

In our discussion of this matter we wish to consider steel as of two grades, as presented by Mr. Dorsey. In order to determine which of the two grades, as presented by him, is the better suited for heavy guns, we cannot do better than consider the peculiarities of these grades.

The advantages possessed and claimed for mild steel are cheapness and uniformity of product. We cannot do better than attempt to discover why it is that articles made of mild steel are uniform in tensile strength. It has been discovered in working mild steel, either by hammering or rolling, that the bar when first finished is in tensile strength and elasticity far below the standard that might reasonably be expected of it; but it gains in strength and elasticity each hour after rolling, up to the twenty-fourth, inclusive. At that time it seems to gain substantially its maximum strength. The only explanation that can be given of this apparent increase of strength is that, in the last two or three passes which the bar makes through the rolls, the steel is reduced very slightly in diameter, the object being simply to remove the scale and to get a perfect surface. This condenses the steel upon the surface to a slight depth, and is in reality an element of weakness rather than strength to the bar as a unit. But a cold flow of metal sets in, and if the steel is so soft that the particles can move among themselves, in twenty-four hours the steel comes to a state of rest. This cold flow of metal will not take place of itself unassisted in high steel, which I will show later.

One great objection to mild steel for artillery purposes is its extreme softness, and its incapacity to resist friction. The rifle of a gun formed of mild steel would not be durable, and after a few rounds would be unreliable, so that the shot or shell would fail to rotate properly. Mild steel has been found to answer excellently for rolls for rolling "blooms" or "flats" where there was no motion between the ingot

and the roll; but whenever rolls have been made of it for rolling shapes where there was a motion between the ingot and the roll, they have completely failed. I know of a set of rolls made for rolling wire stock, of a diamond shape, of superior open-hearth steel, that lasted only five hours, whereas a roll of ordinary gun metal would have lasted as many weeks. Mild steel has therefore been abandoned for this purpose, and the wear of shot or shell on the rifle of a gun would be similar.

In constructing a gun, I consider that the first requisite is that the steel should be in a state of absolute rest. To show the necessity of this condition of the metal, I will refer you to some experiments that were made with the Delafield gun, which I made in 1861 or 1862. This was a cast-iron gun reinforced with wrought iron, as in Parrott's twenty-pounder of the same size bore. Sixty-four of these guns were made, all of which were tested and proved satisfactory. One was fired a thousand rounds, and then fired with double the usual charge of powder and double shot, without fracture. One of these guns, after being rifled and finished, with the exception of putting on the "reinforce" and turning up the trunnions, was found defective in one of the trunnions, and was therefore never finished. The casting lay in the yard, exposed to summer's sun and winter's cold, for five seasons, and by the expansion and contraction caused by the variation of temperature the particles of iron became absolutely at rest. At that time our engineer's little boy was drowned. The gun was taken to the edge of the dock and fired, with the hope thereby to cause the body to rise. The gun was loaded with an unusually heavy charge of powder, and filled with brick and dirt clear to the muzzle. It lay on the ground, and the recoil was so great that the gun was thrown twenty feet from the position of firing, without any fracture. I would also state that these guns were found to be too light to shoot straight, and three hundred pounds were afterward added to the muzzle.

The only objection that is raised to steel of high tensile strain for guns is the want of uniformity of the articles that are made of it. This want of uniformity is owing to the want of proper care in working or manipulating the steel after it has been cast in the ingot. It is well known that an ingot of high steel can be cast more free from blow-holes than low steel, from the fact that it is more fluid, melting at a lower temperature, and therefore allowing whatever gas may be in the steel a better opportunity to escape from the ingot mould in the process of cooling. The only difficulty arising in its working or

manipulation comes from the fact that where the steel is dense, by increased percentage of carbon or otherwise, the cold flow of metal is prevented by its density, and takes place so slowly that, for practical purposes, it does not exist.

A few years ago the firm of John Robinson & Co., of Brooklyn, received a contract to coat with lead an electrical wire that had previously been insulated with gutta-percha, so that it would present the appearance of being formed in a lead pipe. It was necessary that the lead pipe should be formed around the gutta-percha cold, in order not to destroy the gutta-percha. For this purpose they had a block of steel forged eighteen inches long, twelve inches wide, and about ten inches deep, of the highest grade of steel. In the centre of this block was bored a two-inch hole, into which the lead was cast, allowed to cool, and then by hydrostatic pressure was forced around the electrical wire. As soon as the machine was started, before any great amount of pressure was put on, the block split lengthwise, not resisting the strain as well as ordinary gun metal. The fracture was as straight as, and more uniform than, it would have been in a pine block. This firm, supposing that they had not been dealt fairly with by the parties who furnished the steel, had sections taken from different portions of the block, and found that from one portion of the block they got a tensile strain of 111,000 pounds per inch, and on another portion of the block, not ten inches from where this specimen was cut, they got only 52,000 pounds; showing that, although the block had been forged a month, no cold flow had taken place sufficient to produce a uniformity throughout the block. If the steel had been annealed with sufficient care, its particles would have rearranged themselves and become perfectly homogeneous. On inspecting this block, I found that it was apparently a very nice piece of forging. Great pains had been taken to produce a splendid surface and perfect angles. The block had received undoubtedly an immense number of light blows, in order to present a finished surface, and each blow that the block received which failed to condense the metal equally through and through the entire mass was an element of weakness rather than of strength. The light blows had condensed the steel on the surface to such an extent that it was not in a condition to bear the internal strain of the hydraulic pressure.

I wish to show here that the annealing which I recommend for high steel must be done with extreme care, because it is found in practice that the particles of steel arrange themselves independently

of the grain or fibre given to the mass by the previous hammering or rolling. The grain is dependent upon the chemical affinity of the alloy; therefore it is found in practice that the same grain and tensile strength can be got by skillfully annealing which can be got by first hammering and then annealing; so it would appear that the process of hammering or rolling could be dispensed with, and, in my opinion, it will be in future. One great advantage of getting the grain by annealing is that, if the annealing is carefully done, the grain is perfectly uniform throughout the entire mass, the same as in the old-fashioned cast-iron gun; and by carefully examining a portion of the metal at the muzzle, you can rely upon uniformity throughout the entire gun. This, you know, is the basis of proceeding of the "Terre-Noir" process. One great advantage of this process is the great uniformity of its capacity to resist strain in all directions.

Mr. Dorsey refers to the tensile strength given to steel by immersing it in an oil-bath as wholly superficial, since the effect of the oil is only skin-deep. He is evidently here mistaken, and has not arrived at his conclusions from practical observation, as has been shown in the papers that have just been read. I consider the effect of immersing steel in an oil-bath as purely mechanical.

To show the effects of oil upon steel, I will give you my experience with a steel boiler that I had made of mild steel about ten years ago. We found, after using the boiler for a week, that the plates over the fire began to warp, the boiler was elongated on the bottom, and the tubes consequently began to leak. The makers of the boiler were called in for an explanation, but they failed to discover the cause, and undertook to prevent further warping by introducing heavy braces, without any advantageous effect. After having the boiler examined by various experts without any satisfactory results, it was suggested by an uneducated man that there must be some oil affecting it, as he had noticed some very unaccountable effects produced by the presence of oil in boilers. We opened the handholes of the boiler and made a close examination. We found appearances of oil near the water-line, but no indications of it over the fire where the plates were warped; but we did find a light coating or deposit of carbon. This we traced to the decomposition of the oil that was held by the water in suspension, mechanically. We were using a compound engine with a surface condenser about forty feet above the hot well. The condensed steam, being forced directly into the boiler while hot, thus kept up the circulation. I had a filter constructed which removed the oil,

had my boiler cleaned, and my trouble disappeared. The slight coating of carbon which was found on the inside of the boiler acted as an excellent non-conductor, preventing the action of the water on the steel, and hence the warping or twisting.

Now, when a piece of heated steel is immersed in an oil-bath, the portion of the oil in contact with the steel is immediately decomposed. The steel is covered with a light coating of carbon such as my boiler received, only of much greater thickness, which protects the steel from the further direct action of the oil. The surface of the steel is thereby reduced in temperature, and by its contraction compresses the grain of the steel throughout the entire mass, changing the grain and structure of the steel, making it uniform throughout, provided the steel is of uniform thickness and size. If there are parts of the bar or casting that are of much greater thickness than the adjoining parts, there is liable to be a weak point at the junction.

Captain ROGERS BIRNIE, JR., *Ordnance Department United States Army.—Mr. Chairman and Gentlemen :*—The points upon which I shall mainly take issue with the paper are, first, to show how inaccurate is its conception of the qualities of gun steel, and state in this connection briefly what these qualities really are; second, to enumerate some of the more serious objections to the use of the ordinary mild steel of commerce for making guns.

We have no need to discuss the wide range of the so-called hard steel mentioned. The metal which we use for guns is a relatively low steel, such as the French denominate *acier doux*, seldom containing more than 0.45 per cent. of carbon. It gives, before treatment, an ultimate resistance of from 70,000 to 90,000 pounds per square inch, and by judicious treatment, annealing before and after oil-tempering, its qualities are improved for the purpose of gun construction. It is not capricious or unreliable when properly treated, and I can exhibit specimen bars which were taken in the ordinary course of tests from the interior of forgings and have been bent nearly double when cold without fracture. Besides which, examination of the fractures of the many tensile specimens that have been taken plainly indicates a tough and ductile metal. The arbitrary limit of 90,000 pounds used to fix the border-line of capricious and unreliable steel must be raised much higher, if, indeed, there is any such definable limit for a metal which can be so readily adapted to a wide range of uses in the arts, and can, with proper care in manufacture, such as in

a knife-edge, for instance, be made reliable for its purpose, although capable of resisting a compressive force of about 400,000 pounds per square inch.

When we come to condemn the qualities of any given steel, an intimate knowledge of the circumstances attending its manufacture is essential to determine the cause of the failure. Bad workmanship will make poor material of mild steel or any other kind. On the other hand, we know that in proportion to their facilities steelmakers in our own country can turn out a highly uniform and reliable quality of the gun steel required.

A somewhat intimate knowledge of the tests of the gun steel supplied to the Army Ordnance Department within the past four years enables me to collate some facts which, I believe, will materially relieve the fears of the author and those who may think with him in regard to the nature of the steel we are using.

The hoops were first taken in hand, and two sample hoops furnished by the Midvale Steel Co. were subjected to special tests, besides the specimen tests. These hoops were about forty-five inches interior diameter, four inches thick, and 5.625 inches in length. One, which contained considerably the higher percentage of carbon—over 0.2 per cent. more than I have previously mentioned as the maximum generally used for gun steel—was simply annealed after forging and rolling; the other, a prototype of our present hoop steel, was annealed, oil-tempered and again annealed.

A number of bars were cut from the ends of the forgings, outside, inside and middle, for test. The mean of the three-inch bars—four for each hoop—gave the following:

| | Elastic Limit. Pounds. | Elastic Extension. Thousandths. | Ultimate Resistance. Pounds. | Ultimate Extension. Per cent. |
|---|---|---|---|---|
| Annealed hoop, | 46,260 | 1.50 | 102,500 | 17.85 |
| Oil-tempered, | 56,260 | 2.42 | 99,250 | 19.38 |

The two hoops were fine finished and then heated and shrunk upon a cast-iron cylinder. They remained in this strained position for about ninety hours, during which time the interior of the annealed hoop was stretched 1.68 thousandths, and the oil-tempered hoop 1.60 thousandths per linear inch. The respective tangential tensions on the interiors were about 48,000 and 54,000 pounds per square inch. But on cutting away the cast iron each hoop sprang back very nearly to its original dimensions. The restoration of the oil-tempered hoop was practically complete.

Again the hoops were heated and shrunk upon a cylinder, but this time with double the previous shrinkage. They remained thus for seventy-two hours with their respective interior diameters (or circumferences) stretched 3.137 and 3.0 thousandths per linear inch, or under tangential stress of about 84,000 pounds per square inch for the annealed, and 77,000 pounds per square inch for the oil-tempered hoop. When the cast iron was cut away the permanent set of the annealed hoop was found to be 1.19 thousandths, and of the oil-tempered 1.08 thousandths per linear inch. That is to say, their elastic restoration was nearly two-thirds of the excessive strain which had been maintained for seventy-two hours. Neither hoop exhibited the slightest sign of fracture.

The results of these tests led to the adoption of the naturally softer steel, oil-tempered and annealed, which was proved to be in every way superior to the annealed hoop in elastic power. But in the other hoop we have an example of the capabilities of steel if properly manufactured. The metal had a tenacity of over 100,000 pounds per square inch, and it was not oil-tempered, yet it was splendid material, and was rejected for gun construction only because it was tested beside what was considered a somewhat better steel for gun hoops.

Since these tests were made, some twelve lots, comprising over one hundred and fifty gun hoops, have been accepted. They have all been made of the medium low steel, oil-tempered and annealed, and are at least as good as the sample hoop first tested.

The scope of several subsequent shrinkage experiments was enlarged, to test the accuracy of our theories of gun construction, as well as the qualities of the metal, and the results, I may say, have been highly satisfactory.

One incident in connection with these tests was as follows: After building up by shrinkage a compound cylinder 7.5 inches in length, as an exact counterpart of a section of an 8-inch steel gun over the chamber, it was left undisturbed for several weeks, and at the end of that time was dismantled by cutting off the outside pieces consecutively. Whilst the outer hoop of this section remained in place, its interior was extended 1.14 thousandths per linear unit, corresponding to a tension of over 45,000 pounds per square inch. The hoop was loosened by cutting through lengthwise on one side. It was then sprung open by wedging and removed from the section. Notwithstanding this treatment, the hoop when left to itself resumed exactly its circular form, and showed a permanent extension from its original dimensions of but 0.07 thousandths per linear unit.

An important deduction drawn from all these shrinkage tests is that the elastic properties exhibited by the cylinders as a whole are, within narrow limits, the same as like properties determined by the free tests. In other words, the free tests afford us reliable data for constructing the guns. I conclude that this is due to two causes: first, that the metal is very uniform, and second, that when the cylinders are shrunk together, the strain to which they are subjected is uniform in character for the concentric laminae into which they may be conceived to be divided.

I will now give some examples of the specific effects of the oil-tempering and annealing treatment.* The following, taken from the report of the Chief of Ordnance for 1885, page 453, shows the excellent effect produced upon a plain cylindrical hoop forging for a 12-inch rifle. The interior diameter of the hoop was thirty-nine inches nearly, and its thickness 3.625 inches. The specimens were taken tangentially 1.5 inches from the end faces and were six inches in length:

| | No of Specimen. | Position of Specimen. | Elastic Limit. | Elastic Extension. | Tenacity. | Elongation after Rupture. | Reduction in Area. | Specific Gravity. | Hardness. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Lbs. | Thous. | Lbs. | Per ct | Per cent. | | |
| Before treatment | 1 | Inside | 34,000 | 1.333 | 83,600 | 18.33 | 39.2 | 7.8575 | 14.9 |
| | 2 | Outsi'e | 37,000 | 1.367 | 88,000 | 20.50 | 33.5 | | |
| After treatment. | 3 | Inside | 55,000 | 2.100 | 101,660 | 12.5 | 33.5 | 7.8632 | 19.81 |
| | 4 | Outsi'e | 55,000 | 1.833 | 107,160 | 12.83 | 30.6 | | |
| | 5 | Middle | 53,000 | 1.833 | 102,400 | 13.67 | 33.5 | | |

The average qualities of the metal before treatment were: Tenacity 86,000 pounds, elongation nineteen per cent., and reduction of area 36.3 per cent. The effect of the treatment upon the average qualities was to raise the elastic limit, in round numbers, 19,000 pounds, elastic extension 1.9 thousandths, tenacity 18,000, and hardness five per cent., while the elongation was lowered to thirteen per cent., and the contraction of area to 32.5 per cent. only.

* See also Exhibit I. Addenda.

Another example was found in some special tests of a forged trunnion hoop, to which reference will be made, in order to show the outcome of the treatment upon an irregularly shaped and comparatively thick mass of metal. The rough-finished forging, after the ends had been cut off for tests, weighed 2568 pounds. Its interior diameter was 23.25 inches, length 13.8 inches, and average thickness 4.875 inches; whilst on the line of the axis through the trunnion masses the dimensions of solid metal were 12.625 inches. Besides four tangential six-inch specimens taken from each end of the hoop, ten additional ones were taken from a ring cut from the middle length of the forging through the trunnion masses. The actual mean results of the tests of these ten specimens follow herewith in comparison with the minimum requirements of the specifications, which were placed relatively low because the work was experimental:

| | Elastic Limit. Pounds. | Elastic Extension. Thousandths. | Ultimate Resistance. Pounds. | Ultimate Extension. Per Cent. |
|---|---|---|---|---|
| Actual . . . . . | 48,300 | 1.623 | 86,625 | 17.81 |
| Minimum requirements | 42,000 | —— | 88,000 | 12.00 |

This metal was somewhat above the limit in carbon which has been stated, and the good effect of the treatment prescribed may be judged from the fact that two specimens taken from the hoop after forging, but before treatment, showed: Tenacity 103,967 and 104,453 pounds, elongation nine and seven per cent., and contraction 8.2 and 6.28 per cent. The very poorest results obtained from any one specimen of the eighteen taken after treatment were: Elastic limit 46,000 pounds, tenacity 88,960 pounds, elongation 14.5 per cent., and contraction of original area 47.2 per cent. Here, starting with a higher grade of steel deficient in ductility, the treatment reduced the tenacity, but corrected the ductility.

One-half of the hoop was preserved and subjected to shrinkage tests for elasticity and strength like those previously mentioned. In the first, the half hoop was distended to equal very nearly the average limit of elastic stretch determined by the free tests, and its restoration was nearly perfect when the cast-iron cylinder was cut out. In the second test this distension was more than doubled. And in this test, although the final permanent set was more marked on the diameter of the trunnion masses than elsewhere, the average elastic restoration of the hoop on the removal of the cast-iron cylinder was about fifty-five per cent. of the stretch induced by the test.

Many more facts bearing upon the subject might be stated, and in this connection I would refer especially to the results of tests published annually in the reports of the Chief of Ordnance; but I think those already given here will fully support the conclusion that the steel accepted under the specifications mentioned in the paper is not capricious or unreliable and is far superior to the ordinary mild steel of commerce for the purposes of gun construction, for the simple reason, if for none other, that its elastic limit is nearly equal to the ultimate resistance of the mild steel. On the other hand, those specifications are for the plain cylindrical gun hoops only, which form the outer envelope of the gun. And, since the disturbance is inversely proportional to the square of the distance from the centre, the extensibility and ductility of the metal are ample to sustain these hoops much beyond the point at which a gun would become utterly useless by reason of enlargements.

For tubes and jackets, which have to undergo a greater movement, more ductile metal is prescribed. And so on throughout the whole question the various conditions of the problem, founded upon study and the results of experience, are observed.

Having now shown how the steel is benefited for the purposes of gun construction by the treatment—a point which will be emphasized further on—and demonstrated beyond doubt the reliable character of the metal, even in the massive trunnion hoop, I ask the lecturer to kindly furnish us with the data upon which he bases his question about the effect of this treatment. Is his question based upon mere supposition, or is it the result of careful study and investigation? If the latter, then he will perform a very useful service by publishing the details of his experiments, for oil-tempering is now so much used in the treatment of steel for various purposes, that others will be enabled to avoid in the future the paths which led to his failures.

Such experiments in actual firing of guns as we have been enabled to make in the short time that has elapsed since the present line of inquiry was instituted, and with the means at disposal, have given no reason to doubt that the guns we are now making or propose to make will prove other than strong and enduring. The basis of our knowledge is the large experience of foreign nations and gunmakers, who have experimented with guns of various grades of steel, including very mild steel, in the line of the propositions of the present paper, and have finally settled down to adopt the medium low steel, which is substantially what we use in exercising, however, a very rigid and necessary inspection prior to acceptance.

As long ago as 1873, in deference to the opinions then held by Mr. Schneider, an important series of experiments with mild and medium low steel were made at Creuzot, in the interests of the French Government (*Revue d'Artillerie*, Nos. for July and August, 1874).

Short tubes closed at both ends, and guns also, were subjected to powder tests and extreme firing. The steel ranged from a very mild grade containing 0.155 per cent. of carbon, to a medium grade containing 0.3375 per cent. I quote from the conclusions as follows:

"The hardest steel gave the most satisfactory results, and we should, therefore, give it a preference, although tempted to believe that steel of even a little greater hardness would better respond to the conditions that a good metal for guns ought to fulfil."

The metal which gave the best results had an elastic limit of 33,000 and an ultimate resistance of 74,000 pounds per square inch, combined with an extension of but nine per cent. It contained the highest percentage of carbon in the list, and was oil-tempered.

Do the proprietors of Creuzot now recommend the use of the ordinary mild steel of commerce for making guns, and shall we go back thirteen years in progress?

The opponents of tempered steel for guns cannot take great comfort from the recent failures of English guns. We know, for instance, regarding the Collingwood gun, that the tube forging alone failed, and it was the unhooped portion of the chase which burst. Also, that the forging was made some years since, and was not annealed. Gunmakers learn from such failures that their guns should be hooped to the muzzle. And, although we do not practise such negligent treatment of our forgings, those of our manufacturers and others who think the Government requirements too rigid may well take a lesson from such failures.

There are many reports and contradictions concerning the bursting of steel guns made abroad, yet Mr. Krupp deliberately wrote in 1878 (page 791 Jean's "History of the Manufacture and Uses of Steel," London, 1880) that, of the 17,000 of his guns made since 1847, only eighteen had failed, and those mainly in experimental firing to extremity, or on account of the square angles in the slot made for the breech block, which defect he had remedied. No doubt he excluded from this list a mention of guns in which the breech mechanism had become temporarily disabled; but he was not then, nor are we now, discussing the question of breech mechanism.

I have made no mention of the work of our own Navy, because

those gentlemen are present to speak for themselves, but I tender them hearty congratulations upon the splendid progress they have made.

The lecturer advises the use of the ordinary mild steel of commerce for making guns. It has, he says, a tenacity of from 55,000 to 65,000 pounds per square inch; but from another part of his paper we learn that if a plate (or forging?) is more than three inches thick, the *maximum* tenacity would be below 55,000 pounds per square inch, and this tenacity would continue to decrease at a rapid rate with an increase of the thickness of the plate. It would be perfectly proper to argue from this that plates greater than three inches in thickness cannot be made from mild steel, since near this point the tenacity places the metal below the minimum limit used to define mild steel.

It is reasonable to suppose, however, that with an expenditure of the requisite amount of money and brain-work, the manufacturers could turn out the large forgings of this mild steel quite uniform in character and of a tenacity indigenous to that grade of steel, or, let us say, 60,000 pounds per square inch; but that would be a different affair from the present cheap production. Now, this steel cannot be commended for gun construction by virtue of its tenacity as against another steel having a tenacity of, say, 90,000 pounds per square inch. Then it comes to this—that the great virtue of the mild steel lies in its ductility and a capacity to hold together, and to bend or bulge without fracture when heavily strained. There is also claimed for this steel the property that it is incapable of taking temper.* These may be excellent qualities for the purposes of the bridgebuilder, boiler-maker or architect, but they hardly serve the purposes of the makers of springs, tires or guns. The chiefest merit of the metal constitutes a most serious objection to its use for these purposes. It is true we require great strength in a gun, but that is a secondary consideration to precision. A quick falling off in the accuracy of shooting of the gun, due to deformation, is a calamity only less in degree than the bursting of a gun, because it would not endanger the lives of the cannoneers, but it would, just the same, defeat the purpose for which guns are made.

Then, too, the increased dimensions and weight necessary to make a sufficiently strong gun of steel of low tenacity would entail expense and many difficulties. The transportation of the piece, facility

* Competent authorities state that no steel is wholly incapable of taking temper.

and expense of manufacture and of installation of heavy guns, all impose on the gunmaker the necessity of limiting weight, of simplifying construction, and of economizing material to the minimum required to withstand the action of the charge to be used in producing the effect sought.

A gun is essentially an instrument of precision. An ideal gun, in the sense we are now considering, would constitute one great compound spring, responding stiffly to the pressure of the powder gases and then resuming precisely and invariably its original dimensions.

The quality of spring, or, more correctly, elasticity, is so essential in a gun, and the knowledge that it is expedient to temper steel in order to develop this quality is so universal, that it is in the nature of a last resort and a decided step backward to advocate the use of a grade of metal which is incapable of taking a temper and naturally possesses a low elastic limit.*

It is the marked superiority of steel over other commercial metals in respect to strength, stiffness and extensibility, and of the included attributes, especially elasticity, which renders it the fittest of them all for making accurate-shooting, strong and enduring guns, at least in the large calibres.

Gunmakers, then, in order to properly utilize the inherent qualities of this metal, aim to produce a steel which will possess the highest degree of elasticity and tenacity compatible with a requisite extensibility and ductility, and thereby insure an absence of brittleness. It is safe to assert that the ideal gun I have mentioned can never be made; but we should not deliberately neglect to utilize the qualities of steel

* I do not know, in considering the remainder of his paper, what the lecturer means by saying in regard to hoops that by putting on work the tensile strength can be raised very high. I do know that there are earnest advocates of cold rolling or working, but then the lecturer cannot expect to cheapen much the cost of guns if this method is adopted, nor can he apply it to the enormous forgings required for the body of the gun.

By cold working the elastic limit of the hoop metal would be raised very high, but its ultimate extensibility would be reduced to possibly dangerous limits. Dr. Woodbridge states ("Notes on Construction of Ordnance," No. 3, Washington, July 20, 1882), concerning a series of tests made at the Washington Navy Yard, "The steel had, when thoroughly annealed, an elastic limit of strain equal to 40,744 pounds per square inch, and a tensile strength of 71,530 pounds, with an extensibility, in a length of 2 inches and a diameter of 0.5 inch, of 30 per cent. After cold hammering under blows acting upon only one pair of surfaces, its elastic limit of strain became 78,940 pounds, its tensile strength 86,580 pounds, with an extension of 14 per cent."

which enable us to approach that ideal, and, as I have before said, we could only drop now into using the ordinary mild steel of commerce as a last resort. In fine, experience shows us that we should not so lower our standard.

All calculations for the strength of built-up steel guns must, for safety, be based upon the elastic strength of the metal. No member of the structure should be strained beyond its elastic limit either in making or in using the gun, else incipient deformation will be begun, to end in inaccurate shooting and undue enlargements or rupture under continued firings.

The bore of the gun should resume its original form after the firing. Here again our ideal is not attainable in practice. It is quite certainly established that metals can receive some permanent set from strains much below our so-called elastic limit, although this is less apt to occur under sudden strains, such as are due to the firing of a gun, than under long-continued strains. Moreover, there are parts of the bore, especially about the seat of the shot, which are apt to be abnormally enlarged, due, probably, in the main, to the mandreling action of the shot-band. But we adopt for the elastic limit of the metal that point of strain* beyond which the momentary displacements cease to be nearly directly proportional to the stresses, and where an appreciable permanent set is observed in the test specimens. Then the guns are put together with all practicable nicety, and so proportioned as to give a fair margin of elastic strength above anticipated powder pressures. We rely, then, upon the principle that the strains to which the different parts of the gun are subjected will shortly adapt them to withstand, without further material change of form, any strain inferior to the highest which preceded it.

The value of a steel for gun construction, assuming that it possesses the other necessary qualities, is, therefore, dependent upon its elastic limit. And if we use soft steel, we ought, at the least, to provide the same margin of elastic strength as in the case of harder steel.

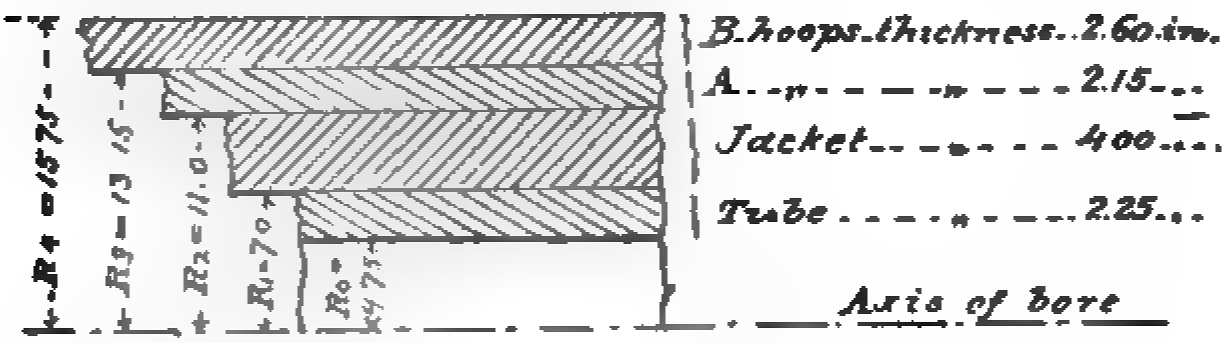
Such expressions of opinion as that a gun may be of "greater theoretical strength, but practically much weaker," need to be very carefully considered before they are enunciated. There exists to-day no more eminently practical profession than that of gunmaking, and none, also, in which the accepted theories have been more rudely or

* Commonly expressed in terms of the stress or the load per square inch which determines this limit of strain.

more crucially tested. No theories are accepted by gunmakers until they have been proved or modified to be consistent with practice.

In order to compare the elastic strength of a gun made of the ordinary mild steel of commerce with one made of gun steel, I shall assume that the mild steel for the whole gun, including the heavy forgings, will possess a uniform tenacity or ultimate resistance equal to 60,000 pounds per square inch, and take the weight modulus of elasticity at 29,000,000 pounds, and the elastic limit at 29,000 pounds or about fifty per cent. of the ultimate strength. The limit of elastic strain will then be 1.0 thousandths of the linear unit.

The following figure shows the radial dimensions of the principal section—*i. e.* the chamber—of an existing 8-inch steel gun which has been fired twenty-four rounds at the Sandy Hook Proving Ground. It is this gun, I believe, to which the lecturer refers in his remarks about thick hoops.




The section in the gun as made is calculated to support without change of form, tangentially, an interior pressure of nearly twenty-five long tons per square inch.

In actual firing it has been subjected to pressures of about sixteen long tons, and the present maximum enlargement near the breech is 0.002 of an inch (on 9.5 inches). In the forward portion of the chamber there is no change. The gun is designed to use a charge which will give a chamber pressure of sixteen tons per square inch. It has, therefore, a margin of fifty-six per cent. of elastic resistance. Now, suppose this gun were made of mild steel. Its elastic resistance would be only fifteen long tons, or two-thirds of what we now have. And to preserve its form equal with that of the present gun we would be compelled to reduce the powder pressure to 9.6 tons per square inch, with a loss of over 200 feet of the present velocity obtained with the standard 285-pound projectile and some 1460 foot tons of energy at muzzle. I do not doubt that a gun could be made of the mild steel with the same margin of elastic resistance as the present gun,

but the weight would be increased from fourteen to about nineteen tons, roughly estimated.

An embarrassment concerning exact deductions as to weight, etc., arises from the uncertainty left in one's mind as to the design of the guns which the lecturer would propose to build. His propositions are exceedingly indefinite upon that point. However, there would be, probably, a large forging to carry the breech block and support the longitudinal strain, which must be distinguished from the tangential resistance already discussed.

The cross-section of the jacket cylinder in this gun (see figure) is 226 square inches, somewhat less than three times the cross-area of the chamber. The pressure in the chamber may reach 40,000 pounds per square inch, and this would place a longitudinal stress, supposed uniform throughout the section, of 15,800 pounds per square inch upon the jacket. This is about one-third the elastic limit of the metal. For the mild steel, with 29,000 pounds elastic limit, the stress should be similarly limited to, say, 10,000 pounds per square inch. The cross-section of the jacket should then contain 283 square inches. There results an increase of twenty-five per cent. in the area, which, in view of the expense attending the manufacture of large forgings, is a very serious objection, and becomes more so when we consider the proportionate increase of a forging for a sixteen-inch gun, which, if made of gun steel, should be nearly four feet across. At all events, the ordinary mild steel of commerce could not be used at all in such forgings if its strength fall off as indicated by the lecturer in his quotations from Lloyd's Register.

The statement that "the strength and reliability of a gun will increase *for the same weight proportionally as the thickness of the hoops decreases* to a practical limit," is misleading, and, if carefully considered, is found to be not true. It would be true only in case all hoops two inches thick, for instance, could be made only a little more than one-half the strength per square inch of all hoops one inch thick, and this presents an absurdity on its face. For we know that if the manufacturer has facilities to put the necessary amount of work on a hoop even four inches thick, he can make it practically uniform in quality with a hoop one inch thick.

Taking a given case, if we double the number of hoops the increase of strength will be very small. I give an example: Substitute four hoops for the two on the eight-inch gun (see figure previously given). The interior radius of the zone embracing the two hoops is 11.0 inches and the exterior radius 15.75 inches. In dividing the thickness

for four hoops we follow the rule that each radius shall be a mean proportion between the two adjoining ones, and find the values to be:

$R_2=11''.0$, $R_3=12''.03$, $R_4=13''.16$, $R_5=14''.4$ and $R_6=15''.75$.

Proceeding from within outwards, the thicknesses are 1.03, 1.13, 1.24 and 1.35 inches.

Assuming all the hoops to be of mild steel having an elastic limit of 29.000 pounds per square inch, the four hoops properly combined by shrinkage would safely support an interior pressure of 5.55 tons per square inch, and the two hoops combined would similarly support a pressure of 5.15 tons per square inch; or, the difference in favor of the four hoops amounts to but 0.4 of a ton, or 900 pounds per square inch. By way of comparison I will observe that the two hoops actually used on the gun can support within their elastic limit an interior pressure of 9.25 tons per square inch.

I fear the lecturer has, perhaps unwittingly, conveyed an erroneous impression to the uninformed in mentioning the thick hoops of the Ordnance Specifications. The thick hoop he mentions was designed for a special purpose in the construction; its thickness is not uniform in finished dimensions, but the maximum is four inches. For the rest, the hoops of this gun (numbering thirty-four in all) are thinner than will usually be found in guns of this calibre.

I will not be understood as advocating thick hoops. It is easier to produce comparatively thin hoops of uniform quality, and there are advantages to be gained in reliability in using them, but not in any such quantity as the lecturer proposes. Moreover, with such a number of hoops the cost of manufacture would be prodigious, and the risk of spoiling a gun by bad shrinkages greatly increased.

In some experiments made not long since in England, it was found that a 6-pounder Hotchkiss shell fired against the chase of a 9.2-inch steel gun at very short range, produced very large bulges in the bore. The danger of this happening would be increased if the gun were made of the mild steel. As to the effect of small shot on the guns, I think the misapprehension under which the lecturer labors concerning the qualities of gun steel has led him to erroneous conclusions. Guns should be placed under cover when practicable; but if I were to propose, for instance, to sheathe the necessarily exposed parts with some material better adapted than steel to make them bullet-proof, it would constitute no argument in favor of making the whole gun of the same material. What takes place within the gun is of transcendent importance compared to the pattering of small shot upon its exterior. On the other hand, if a dangerous shot should strike the

chase, or a small shot enter the bore, it would be more likely to injure a piece made of the mild steel than one made of gun steel.

The propositions of the lecturer involve a radical improvement in the methods of manufacture of the ordinary mild steel of commerce to make it sufficiently uniform for the heavy forgings, also largely increased sizes of forgings and increased weight of gun. They involve the use of many and thin hoops, which would largely increase the cost and difficulty of manufacture. And they involve the prosecution of enough experiments to determine by empirical means alone the proper thickness of these multitudinous hoops with thicknesses varying for the size and use of the gun. On the question, then, of cost alone, gun for gun, it may well be doubted whether the propositions of the paper would, if carried out, bring about any reduction of present prices.

I need not argue to prove that when steel is required for making guns in quantity the metal should be of home production; patriotism demands this, and it is a military necessity. The gun steel we now produce, although limited in quantity, is excellent in quality and compares most favorably with the best of foreign products. This point has been reached by the independent action of energetic and intelligent steelmakers who have followed up this industry in response to the calls of the Department. We cannot depend upon foreign markets for our gun steel, and therefore, instead of trying to throttle the youthful industry in our own country, we should by all just means encourage its development.

Our standard specifications for gun steel conform to-day to qualities which the Midvale Steel Company and Cambria Iron Works have shown their ability to produce in almost if not quite their first attempts. The same high standards should be maintained, subject only to such interdependent modifications as further experience may teach us will render them more appropriate to procure the grades of steel required. These specifications omit any requirements as to chemical composition and leave a fair field for different manufacturers to reach the standard in their own way.

Our national policy is defensive, not aggressive; yet in providing means of defense we must at least equal and should endeavor to surpass the arms that may be brought against us. Let those who design and make boilers be satisfied, if they will, with the ordinary mild steel of commerce, but do not retard progress and discredit our national intelligence by advocating at this late day the use of such steel for guns.

## ADDENDA.

### EXHIBIT I.—*Tests of Gun Steel before and after Treatment.*

Below will be found a table showing the effect of annealing or of oil-tempering and subsequent annealing on several steel pieces manufactured by the Midvale Steel Company for the Department. The results given are from tests made by the Company. It is to be regretted that their testing machine does not determine the elastic limit.

| NATURE OF PIECE. | TREATMENT. | Results of Test before Treatment. | | | Results of Test after Treatment. | | |
|---|---|---|---|---|---|---|---|
| | | Ultimate resistance per square inch of original section. | Elongation after rupture. | Reduction in area after rupture. | Ultimate resistance per square inch of original section. | Elongation after rupture. | Reduction in area after rupture. |
| | | Pounds. | Per cent. | Per cent. | Pounds. | Per cent. | Per cent. |
| Tube for 3.2-inch rifle | Annealed | 100,500 | 10.5 | 15.6 | 87,700 | 16.0 | 20.0 |
| Tube for 8-inch converted rifle | " | 80,400 | 9.0 | 8.0 | 71,500 | 25.5 | 39.7 |
| Jacket for 3.2-inch rifle | Oil-tempered and annealed | 95,068 | 12.5 | 13.0 | 102,900 | 14.5 | 22.0 |
| Hammered hoop for 8-inch rifle | " " " | 88,900 | 20.5 | 33.0 | 106,600 | 17.5 | 35.0 |
| " " " " | " " " | 94,100 | 19.5 | 32.0 | 102,000 | 20.5 | 47.0 |
| Rolled hoop for 8-inch rifle | " " " | 89,500 | 21.5 | 31.0 | 100,200 | 17.5 | 35.0 |
| Rolled hoop for 12-inch mortar | " " " | 97,500 | 21.0 | 28.7 | 107,000 | 18.0 | 40.0 |
| Rolled hoop for 8-inch rifle | " " " | 89,000 | 18.5 | 27.0 | 107,000 | 19.0 | 39.0 |
| Hammered hoop for 8-inch rifle | " " " | 97,000 | 22.0 | 28.0 | 106,000 | 20.0 | 41.0 |
| Breech block for 12-inch rifle | " " " | 86,132 | 11.5 | 12.0 | 97,720 | 15.0 | 31.0 |
| Breech block for 10-inch rifle | " " " | 84,880 | 24.0 | 41.0 | 94,880 | 20.0 | 41.0 |
| Lever for 12-inch rifle | " " " | 88,400 | 20.0 | 37.0 | 86,920 | 24.0 | 48.0 |
| Spindle for 12-inch rifle | " " " | 103,813 | 5.5 | 5.2 | 97,500 | 17.5 | 29.0 |
| " " " | " " " | 95,820 | 13.0 | 13.0 | 94,700 | 19.0 | 40.0 |
| Rolled hoop for 10-inch rifle | " " " | 85,780 | 22.0 | 34.0 | 101,160 | 19.0 | 34.0 |

**NOTE.—The above is an extract from report of Lieutenant F. E. Hobbs, Ordnance Department United States Army, Inspector at the Midvale Steel Works, August 20, 1884. See Report of Chief of Ordnance, United States Army, 1884, page 430.**

**R. B.**

## EXHIBIT II.—*Tests of Gun Steel, Oil-Tempered and Annealed.*

**Each one of the following sets of results represents some piece which has been accepted and received by the Department, and they include tubes, jackets, cylindrical hoops and trunnion hoops, the specimens being taken at different points of the thickness of the piece, and generally at least 1½ inches from any surface of the piece. Single specimens can be found giving ideal results, but such would not be a fair example. These given are neither the best nor the worst on which material has been accepted.**

| NATURE OF PIECE. | TREATMENT. | Results of Test after Treatment. | | | | |
|---|---|---|---|---|---|---|
| | | Length of specimens. | Elastic limit. | Ultimate resistance. | Elongation after rupture | Contraction of area. |
| | | Inches | Pounds. | Pounds. | Per ct. | Per ct. |
| Hoop for 8-inch steel rifle... | Oil-tempered and annealed | 3 | 59,000 | 103,080 | 17.33 | 36.4 |
| " " " .. | " " " | 3 | 59,000 | 103,120 | 17.67 | 36.4 |
| " " " .. | " " " | 3 | 60,000 | 101,840 | 18.00 | 39.2 |
| Hoop for 10-inch steel rifle... | " " " | 6 | 57,000 | 100,240 | 15.33 | 39.2 |
| " " " ... | " " " | 6 | 56,000 | 100,560 | 17.4 | 45.2 |
| " " " ... | " " " | 6 | 54,000 | 98,520 | 14.7 | 29.5 |
| " " " ... | " " " | 6 | 64,000 | 110,040 | 15.5 | 47.2 |
| " " " ... | " " " | 6 | 62,000 | 110,320 | 14.5 | 35.8 |
| " " " ... | " " " | 6 | 65,000 | 111,480 | 16.0 | 33.3 |
| " " " ... | " " " | 6 | 68,000 | 112,760 | 15.0 | 33.3 |
| Hoop for 12-inch B. L. mortar | " " " | 6 | 57,000 | 106,440 | 12.67 | 39.2 |
| " " " | " " " | 6 | 58,000 | 104,120 | 14.60 | 37.8 |
| " " " | " " " | 6 | 55,000 | 100,240 | 14.00 | 42.8 |
| " " " | " " " | 6 | 58,000 | 105,880 | 11.67 | 40.5 |
| " " " | " " " | 6 | 58,000 | 103,000 | 17.0 | 49.7 |
| " " " | " " " | 6 | 59,000 | 101,200 | 13.0 | 52.2 |
| " " " | " " " | 6 | 59,000 | 104,240 | 15.0 | 49.7 |
| " " " | " " " | 6 | 59,000 | 105,560 | 13.83 | 44.6 |
| Tube for 3.2-inch steel rifle... | " " " | 2 | 54,000 | 94,600 | 26.5 | 43.3 |
| " " " ... | " " " | 2 | 53,000 | 91,900 | 23.5 | 43.3 |
| " " " ... | " " " | 2 | 49,000 | 86,450 | 25.0 | 51.9 |
| " " " .. | " " " | 2 | 49,000 | 88,800 | 21.0 | 43.3 |
| " " " ... | " " " | 2 | 54,000 | 96,600 | 25.0 | 49.1 |
| " " " ... | " " " | 2 | 53,000 | 94,000 | 26.0 | 49.1 |
| Jacket for 3.2-inch steel rifle | " " " | 2 | 48,000 | 88,150 | 28.0 | 51.9 |
| " " " | " " " | 2 | 51,000 | 90,700 | 25.0 | 49.1 |
| " " " | " " " | 2 | 50,000 | 88,050 | 29.0 | 51.9 |
| " " " | " " " | ... | 55,000 | 97,500 | 21.0 | 43.2 |
| " " " | " " " | ... | 54,000 | 97,550 | 24.0 | 46.7 |
| " " " | " " " | ... | 53,000 | 94,700 | 19.5 | 39.2 |
| Tube for 8-inch converted rifle | " " " | 3 | 49,000 | 86,840 | 23.33 | 49.7 |
| " " " | " " " | 3 | 51,000 | 90,400 | 20.0 | 52.2 |
| " " " | " " " | 3 | 46,000 | 86,200 | 21.0 | 52.2 |
| " " " | " " " | 3 | 41,000 | 77,780 | 25.0 | 54.6 |
| " " " | " " " | 3 | 45,000 | 83,000 | 24.33 | 44.6 |
| " " " | " " " | 3 | 42,000 | 78,640 | 27.0 | 54.6 |
| " " " | " " " | 3 | 49,000 | 89,040 | 20.33 | 47.2 |
| " " " | " " " | 3 | 44,000 | 81,680 | 26.33 | 49.7 |
| " " " | " " " | 3 | 47,000 | 90,160 | 20.00 | 39.2 |

**NOTE.—The above results were compiled by Lieutenant F. E. Hobbs, Ordnance Department United States Army, Inspector at the Midvale Steel Works and Cambria Iron Works, from recent fabrications.** R. B.

At 11 P. M. the Chairman took the floor and called attention to the lateness of the hour, asking the sense of the meeting with regard to continuing the session. Lieutenant Ingersoll moved that Lieutenant Austin M. Knight, U. S. N., be invited to read his paper. The motion was seconded and carried.

Lieutenant Austin M. Knight, *U. S. N., in charge of Naval Proving Grounds, Annapolis, Md.—Mr. Chairman and Gentlemen:* —The writer of this paper comes before the Institute and the public as a civil engineer of ability and established reputation. He speaks from experience and with authority upon the use of steel for bridges, for boilers and for shipbuilding. To his assertions regarding the qualities of steel best suited for these purposes, officers of the Army and Navy will take but little exception. It is not with such applications of steel that their experience or their studies qualify them to deal. Conversely, it seems not unfair to remark that the experience and studies of a civil engineer, unless they have taken a direction outside the ordinary lines of his profession, do not qualify him to speak with special authority upon the construction of ordnance.

That the present lecturer's experience and studies have not taken such exceptional direction, seems clear from this paper. The quality by which alone he defines steel—its ultimate breaking strain—is one of primary importance to the civil engineer, but of altogether secondary importance to the gun constructor. So much is this the case, that by some manufacturers the ultimate tensile strength is entirely disregarded in the acceptance of steel, the elastic limit and elongation being alone considered. By those manufacturers who demand a specified tensile strength, far less weight is attached to it than to the elastic limit, and *percentage of elongation within that limit.*

Again, the sole authority cited by the lecturer is the Chief Engineer of the English Lloyd's, whose opinion about steel would naturally have greater weight with a civil engineer than with a designer or manufacturer of ordnance. And even from this authority he gives us, not an opinion as to the material of which guns should be built, but only a specification for boiler plates and stays. Now, it may be possible to establish an analogy between the strain upon a gun and that upon a boiler, but certainly the analogy is not apparent, and no attempt is made to establish it in this paper. Instead of accepting such a specification, from such a source, as a guide to the design and

construction of ordnance, officers having this work in charge would, I should suppose, look rather to the practice of those large establishments whose needs are similar to their own and whose experience has been with steel, not in small plates and bars, but in such masses as those in which it is to be used for guns. Such establishments are those of Sir Joseph Whitworth, of Firth, of Schneider, of Krupp; at Terre Noire and at Aboukhoff. Every one of these establishments, except the last-named, is engaged in the manufacture of guns or gun steel as a commercial enterprise. Their work is in the market of the world, seeking recognition and a financial return for immense sums of money invested. The failure of a single one of their guns has an immediate and marked effect upon the demand for similar guns. Government ordnance officials may, in some cases, be wedded to theories or methods which are not the best; but the firms enumerated above can have no other aim than to produce the best possible article. They command unlimited capital and can secure the highest ability of the world in their scientific experts. They have had years of experience, during which we may be sure they have not failed to look closely into the cause of every accident that has occurred to their own or other guns. Nor are they likely to have omitted any tests by which the effect of the processes upon which they rely—whether oil-tempering, annealing, or any others—could be determined. These establishments are unanimous in the belief that the material which the lecturer utterly condemns for gun construction is the very best material for that purpose. Surely, their testimony and practice, based as it is upon actual experience, not with ships and bridges, but with guns, should more than offset the latest specifications of Lloyd's Register for boiler plates and stays.

The present discussion is practically a renewal of the old contest of twenty years ago between wrought iron and steel; a contest which ended about 1870 in the decisive victory of steel. An eminent American civil engineer, Mr. Alexander Holley, who, to the familiarity with these metals due to his experience as an engineer, added that derived from special investigation of the subject of ordnance and armor, wrote of that controversy as follows: "Mr. Anderson, Sir William Armstrong, Mr. Mallet and others, complain, in various public statements, that most of the steel they have experimented with for guns is too brittle; that it gives way under *sudden* strains which wrought iron will stand. Hence steel—especially high steel—has been condemned as a cannon metal.

"In answering this objection, let us briefly review what has been said under the head of 'Ductility.' Suppose two thin tubes of equal size, one of high steel and the other of wrought iron, to be subjected to the violent and sudden strains of gunpowder. The elastic limit of the steel is overcome and it soon breaks, because it has but a small reserve of ductility to draw upon to eke out its integrity. The elastic limit of the wrought-iron tube is overcome much sooner, but it has an immense capital of ductility to expend, and so it stretches and stretches for a long time without fracture.

"Now, suppose the quantity—thickness—of steel to be increased just so much that the pressure will never overcome its elastic limit; that is to say, so that its particles will return to their original position after the pressure ceases. Its original resistance to the next strain is then unimpaired, and there is no evidence that it will ever become impaired.

"But, in order to bear the same pressure, the iron, equally increased in quantity, will stretch beyond its elastic limit, and therefore must depend upon a new arrangement of particles and a new limit of elasticity for continued cohesion. Its great ductility allows this rearrangement to continue for some time; but, although it may stretch to a less distance at each renewed application of the pressure, its ability to stretch and its range of elasticity are constantly diminishing, until it at last arrives at a point where it can stretch no further without fracture. It has exhausted its reserve ductility. If it were not so, iron would never be broken at all by stretching.

"This explains the failure, after short service, of thin tubes made of the moderately high steel heretofore used, while thin iron tubes *appear* to be unimpaired by elongation, although they certainly are impaired from another cause—compression. It is simply a question of excess of metal and, practically, endless endurance on the one hand, and ultimate failure on the other hand."

The steel referred to in the above extract had a tensile strength of from 90,000 to 120,000 pounds.

The lecturer believes that steel of this tensile strength cannot be made reliable and uniform; that it is and must be treacherous. In this, as we have seen, he differs from nearly every firm in the world which has had experience in the manufacture of steel in large masses. Those firms claim that the grade of steel in question can be made of practical uniformity and reliability, though recognizing the fact that its production presents certain difficulties and calls for delicate manipu-

lation and for special treatment after manufacture. If their claim be established, the whole argument against such steel falls to the ground. The question can be settled only by experience.

Whitworth and Krupp have been using their present grade of steel and their present system of construction for about fifteen years; the English, French and Russian Governments for a time considerably less. Of the total number of guns manufactured by them all—a number which must amount to several thousand—some five or six have failed in such a way that the failure may have been due to defective steel.

It is true that a large number of Krupp guns were rendered unserviceable by their own fire during the Franco-Prussian War. But this had nothing to do with the steel of which they were composed. The failure was in the breech mechanism. On page 83 of a "Treatise on the Construction and Manufacture of Ordnance," prepared in the English Gun Factory and published in 1877, is the following note, doubtless from the same authority that the Duke of Cambridge quoted in the House of Lords, as mentioned by the lecturer: "The complication due to the breech arrangement was in fact severely felt during the war of 1870–71, when over 200 guns were rendered unserviceable in the field through the breech mechanism becoming defective." The same work gives a list of steel guns which had exploded between 1860 and 1877, from the information in the possession of the English Government. No mention is made of any such accident to a Krupp gun during the Franco-Prussian War.

The Krupp gun, however, of the period up to the close of that war, has but little connection with the present subject, as it was not a built-up gun. It was made from a single ingot of steel, cast and forged, and *not* oil-tempered. When Mr. Krupp—then as now the most extensive manufacturer of, and experimenter with, steel in the world—found reason to believe that his guns could be improved by a change of construction, he lost no time in making the change, but passed at once to the system of building up.

Is it not a significant fact that, with all his knowledge of steel, and considering the radical change he was making in his guns at that time, he found no reason to reduce the tensile strength of his steel, which was then, as now, about 100,000 pounds?

In this country we have lately begun the construction of ordnance from steel similar to that used by Whitworth and Krupp. Our manufacturers took up the matter of producing this high grade of

material with limited facilities and no experience. Twelve guns built for the Navy and one built for the Army have thus far been tested. Of the Navy guns the first one was in use for experimental firing with powder and projectiles during sixteen months. In that time it fired 274 rounds, many of them with pressures from thirty per cent. to fifty per cent. higher than the pressures which it and similar guns will have to endure in service. Two of the others have been publicly subjected to an extreme test of rapid firing with the maximum charges allowed for service. In the bores of two of the others loaded shells have exploded at points near the muzzle—the very weakest part of the gun. The remaining guns of the twelve have been tested with full charges and with pressures exceeding those of service. Several of these have fired more than 60 rounds. No failure of any kind has occurred with any of these guns, nor has the slightest evidence of weakness been revealed.

I submit that this does not look as if the material of which they are composed were hopelessly treacherous, and liable to fly in pieces without apparent cause and when subjected to little or no pressure.

The fact is that the record of modern steel guns of the present system of construction, instead of being, as the lecturer assumes, a record of failure, is one of great and remarkable success. In that record is found the best possible experimental proof of the efficacy of those processes whose value the lecturer thinks so doubtful. In their belief in the value of those processes, gunmakers are not alone.

Prof. R. H. Thurston, in a recent work on "The Materials of Engineering," after speaking of the importance of annealing steel to relieve internal stresses, adds, "Masses of steel may be successfully tempered in oil." Mr. Holley, throughout the work which has already been quoted, constantly refers to the value of oil-tempering for large masses of steel, without intimating a doubt that its effect extends throughout the mass.

With regard to those guns which have failed apparently through the treachery of the steel, it may perhaps be questioned whether the explanation of their failure lies in an overestimate of the strength of the material or an underestimate of the strain which the material would have to stand. It seems to me that in some cases the manufacturers of powder and the manufacturers of guns have failed to work together as they should have done. All the efforts of the first have been directed to the production of a powder which should carry the pressure far down the bore. This should have been met, on the part

of the gunmakers, by a corresponding increase in the thickness of the gun along the chase. It has been so met in most recent designs, but in some cases the new powder has been used in old guns; and that the number of accidents resulting from this injudicious combination has been so small, is evidence of the generally excellent quality of the guns, and the satisfactory width of the margin of safety when these guns are used with the powder and pressure for which they were designed.

As bearing directly upon the possibility of making steel of high tensile strength which shall be capable of standing a great pressure suddenly applied, the following extract from the Report of the Gun Foundry Board is pertinent:

"The latest exhibition of the wonderful character of the Whitworth steel has attracted great attention, and may be stated as indicating the present culmination of his success. From a Whitworth 9-inch gun, lately constructed for the Brazilian Government, there was fired a steel shell, which, after perforating an armor plate of eighteen inches of wrought iron, still retained considerable energy.

"The shell was but slightly distorted.

"The tests of the metal of which it was made show a tensile strength of *ninety-eight tons* per square inch and a ductility of nine per cent."

The CHAIRMAN.—*Gentlemen*:—The lateness of the hour makes it necessary to terminate the discussion, although there are several letters and papers still remaining to be read. Among the latter, the Institute would have been glad to listen to the remarks of Lieutenant Jaques, U. S. Navy, and Mr. John Coffin, Assistant Engineer of Cambria Steel Works. All these papers will, however, be printed with the proceedings of the evening.

In conclusion, I may say that it is to be regretted that Mr. Dorsey has not been present to hear what has been said upon the other side of the question; I am confident his views would have been materially modified, if he had not been entirely converted to the views which have been so ably presented in the discussion.

I venture to think that a careful comparison of opinions upon this question of hard and soft steel will reveal the fact that there is not much difference of opinion, after all. Mr. Dorsey and those who endorse his views have, I think, assumed that gunmakers are using a much harder steel than is the case.

Although the percentage of carbon in gun steel is double or treble

what is considered admissible in structural steel, yet it is evident that the increased quantity of carbon produces a quality of steel which is thoroughly reliable when properly tempered and annealed, while it possesses at the same time the immense and indispensable advantage of a high elastic limit.

Commander P. F. Harrington, U. S. N., then moved that a vote of thanks be tendered to Mr. Edward Bates Dorsey for the valuable paper contributed to the Institute, and to the gentlemen who have given us the pleasure of their presence and the benefit of their views. The motion was seconded by Professor N. M. Terry and carried unanimously. The meeting adjourned at 11.30 P. M.

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Mr. JOHN COFFIN, *Assistant Engineer of the Cambria Company, Johnstown, Pa.—Mr. Chairman and Gentlemen* :—It seems to me absurd that, from knowledge gained by a study of structural steel, with a confessed ignorance of the methods of treatment and character of gun steel, a man should attack the work done by our Ordnance Departments. The history of steel guns extends but a few years, but, short as it is, it has not been a history of failure. It seems wonderful to me that there have been so few failures in English guns. I have heard a great many stories about English practice (or malpractice) which I believe, because they come to me from reliable witnesses, but they would have no weight here.

It is a known fact that no test pieces have been taken from the tubes after treatment, but that the test pieces on which they are accepted are manufactured separately, as far as the later and most important part of the manufacturing process (the tempering) is concerned. If our ordnance officers should accept a tube in this manner and on this kind of a test, Mr. Dorsey would have some ground for his claim that they were using treacherous material. And here it might be well to understand what constitutes treacherous steel.

If we make gun material of a steel that would give 100,000 pounds ultimate and put it in the gun without testing it; or, as the English do, if we manufactured the test pieces separately, we would have "treacherous steel," as Mr. Dorsey terms it, or steel of unknown qualities; or if we worked the whole ingot up into gun steel and cut the test pieces from the bottom parts, we would have "treacherous steel," as Mr. Dorsey calls it, or dishonest steel.

In structural steel nearly the whole ingot goes into steel bars, and a steel that will weld to some extent in rolling is a safer material. In gun steel one-third of the length of the ingot is thrown away as untrustworthy, one-eighth of the remainder is thrown away from the centre of the ingot; this may be said to be a manufacturing necessity, yet it is a fact that the least dense and weakest metal is at the centre of an ingot; but for structural purposes this is all grist.

The ordnance officers of our government are not following the example of foreign governments. They are profiting by the experience of others and gaining knowledge from their failures, but I trust are not copying their mistakes. Could any pressure be brought to bear on our Congress to cause it to compel our Ordnance Departments to accept material for guns once rejected by them, and are our Ordnance Departments relax enough to allow manufacturers to hoodwink them into a system of testing which permits the considered article and the test piece which represents it to be manufactured separately? To be sure, we have only made a few steel guns in this country, and as the number increases we hope to gain in knowledge of the subject; but as far as we have gone I think it difficult to find any work in this country, or in the world, more scientifically planned or more carefully executed.

Mr. Dorsey asks some very pointed questions about oil-tempering. Surely he must know such questions must be somewhat embarrassing. There are, probably, a great many in this room who have the results in their possession of experiments carefully carried out, and in number enough to convince any one, even the most skeptical, that there was something in the process more than a name; but few of them were tried at the direct public expense, and few people can make them public without a breach of faith; yet, for the benefit of Mr. Dorsey and those who believe with him that the oil or its magic effect can only affect the surface of "so dense a material as steel," I will cite the results of a few experiments. A rolled billet 7" x 7" x 20" was tempered in oil and tests cut from one corner and from the middle. The axis of the first piece was one and a half inches from the surface, and the axis of the second piece was three and one-half inches from the surface. The result gave a difference of only 1350 pounds in elastic limit, the result of both tests being much better than the untreated material. As an illustration of the beneficial results of oil-tempering I give this experiment: A small ingot was cast seven inches square and twenty-four inches long in a cast-iron mould, poured from the top, and

no special pains taken in casting. It was oil-tempered, and a test piece cut from the bottom two inches long, 0.55 inches diameter, gave: Elastic limit, 52,000 pounds; ultimate, 88,500; elongation, 16.7 per cent.; reduction of area, 20.2 per cent. Can Mr. Dorsey or any one else show an equal test from an ingot of this size without hammering or tempering?

Now, what constitutes soft or mild steel? According to Mr. Dorsey's definition he gives the mean tensile strength at 60,000 pounds, and also says it is steel that will not harden. The Navy Department has in its possession tests from tubes of soft steel of 60,000 pounds tensile strength, a few of which I will give:

| UNTEMPERED. | | | TEMPERED. | | |
|---|---|---|---|---|---|
| Elastic limit in tons. | Ultimate strength in tons. | Elongation in inches. | Elastic limit in tons. | Ultimate strength in tons. | Elongation in inches. |
| 13 | 26.8 | .737 | 29.2 | 45.2 | .433 |
| 13 | 27.8 | .707 | 27.8 | 46 | .345 |
| 12 | 27.6 | .713 | 26 | 39.6 | .420 |
| 12 | 28 | .633 | 25.8 | 41 | .480 |
| 13.77 | 28.11 | .596 | 34.15 | 49.8 | .26 |
| 12.18 | 26.9 | .564 | 34.8 | 49.4 | .202 |

These results show beyond question that 60,000-pound steel will take temper. Furthermore, if a strong gun could be made from soft steel, which has been shown to be impossible, I believe the cost could not be reduced, as it would be more difficult to make large ingots from soft steel.

Lieutenant WM. H. JAQUES, U. S. N.—*Mr. Chairman and Gentlemen*:—The theories and opinions presented in Mr. Dorsey's paper have been so effectually refuted in the able discussions to which we have listened this evening, that there remains little or nothing to be said in relation to the technical questions therein. But there is another point of view from which it may be considered, and that is the effect which it and similar papers in the general press may have upon the general public, coming as it does from a *civil*, instead of a *military*, engineer.

At a dinner given by the New England Society in one of our large cities, an Admiral of our Navy, in reponse to the toast, "The Navy," said if the length of his speech was to be governed by the size of our Navy, he had already said too much. I do not recall, at the present moment, anything more pertinent to apply to the paper under discussion, if its application to gunmaking is alone to be considered.

When I heard that it was to be read and discussed to-night, I was opposed to its consideration, for I believed it unworthy of the prestige which publication in the proceedings of this Institute would necessarily give it. But as it has been the means of bringing together the intelligent men whom I see before me, has furnished a motive for an interesting and spirited discussion, and has given an opportunity for the presentation of the opinions of men pre-eminent in their respective professions, I must thank the writer, so far, for his success.

Though he has intimated that his argument is based upon the "experience and opinion of all the principal steelmakers of the world," his several trips to Europe and elsewhere appear to have been fruitless, for we can find nowhere in his paper any opinion that is in accord with the accepted authorities on special steels either in Europe or at home. In fact, as has been so repeatedly said this evening, he has displayed his utter ignorance of the subject he has attempted to discuss.

The arguments to which we have already had the pleasure of listening have so completely disposed of the claims and conclusions contained in his paper, that it is unnecessary for me to do more than to ask you to recall the opinions of various high authorities in the United States who have taken the interest and trouble to give important committees the benefit of their experience and knowledge. A glance at the report of the Senate Committee on Ordnance and War Ships alone will show the wide range of investigation that was conducted. It is needless for me to state that the testimony to which I refer does not accord with the views Mr. Dorsey advocates. Neither does the letter just read from Mr. Wellman. Nor in the letters expressing a preference for his "cheap material" will he be able to find much sympathy, for even Mr. Thurston, by his eulogy on Whitworth steel, at the close of his communication read to-night, completely destroys the value of his argument in the first half, and makes his endorsement of Mr. Dorsey's opinions more injurious than helpful.

What Mr. Morgan and Mr. Davenport have said this evening must convince all who have heard them, and all who will read their discussion hereafter, that our military (employing it in its comprehensive sense, with reference to both branches of the service) engineers have the hearty endorsement of all those civil and mechanical engineers who have made a careful study of the application of steel to ordnance purposes. I will not quote, therefore, from the powerful evidence which they have from time to time given on this question.

Notwithstanding all this positive testimony from the leading managing and mechanical engineers of the country, the advocates of "cast iron" and "mild steel" for ordnance materials claim, in speaking of the failures of guns in Europe: "This is what might have been expected. Every steelmaker who is not a gunmaker says these large masses cannot be forged so as to be safe from injurious strains. Every mechanical engineer who is worthy of the name knows that such masses of rings and tubes cannot be fitted and assembled so as to act as a continuous whole; and even if they were so fitted, they could not be retained in that condition after the warming up of the first few rounds."

Does the evidence to which we have referred endorse either of these unwarranted statements? Are they proved by the splendid treatment that Whitworth and Schneider give their metal, and by the interesting experiment made by Sir Joseph Whitworth to illustrate the effective power of shrinkage?

[*From Proceedings Naval Institute*, No 31.]

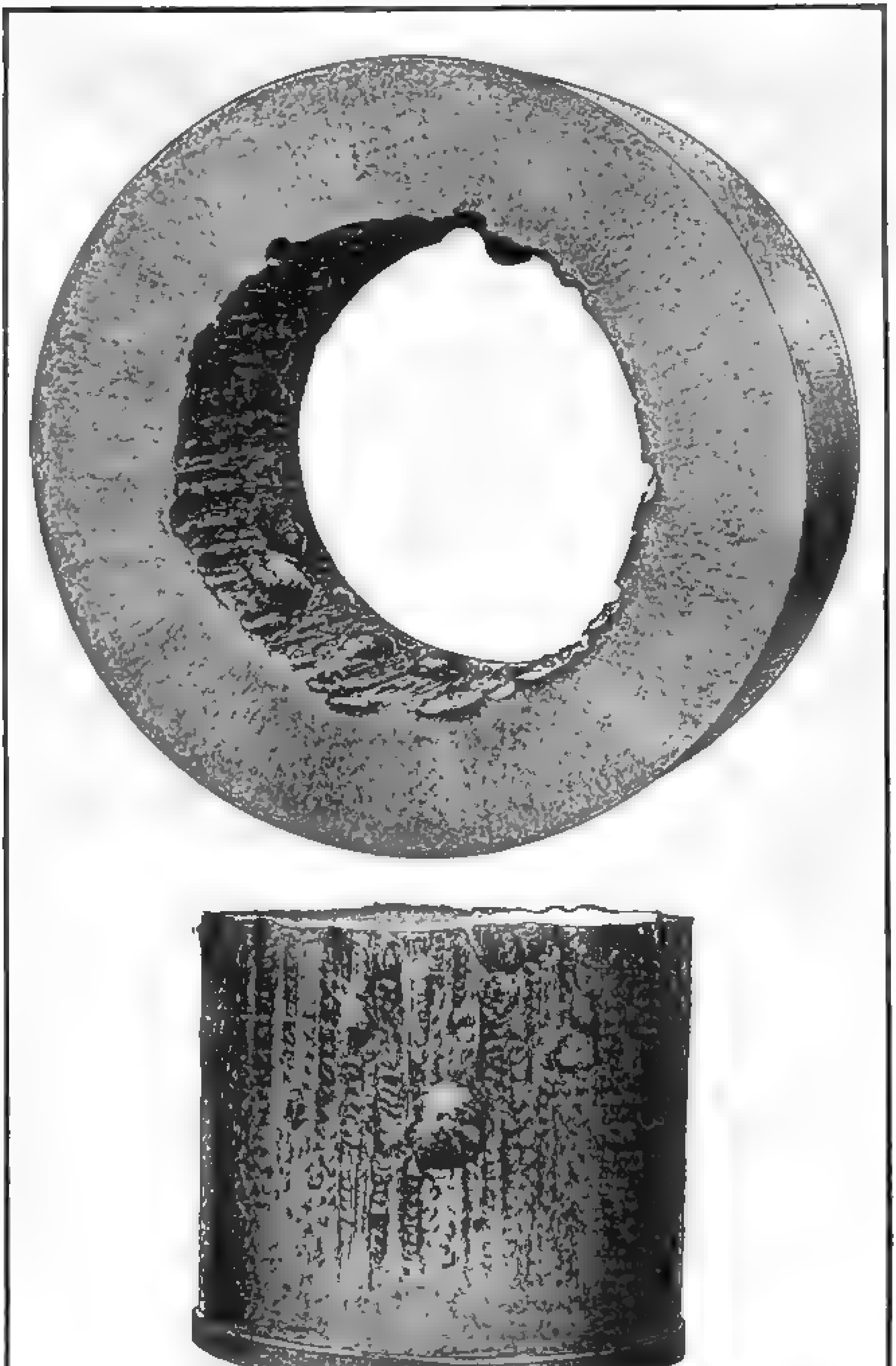
"Plate XXXVI. presents the result of a most important and interesting experiment made by Sir Joseph Whitworth to illustrate the effective power of shrinkage. The ring was made of mild, fluid-pressed steel, and was heated and shrunk on to a plug 18 inches in diameter. When cold, the plug was forced out by an hydraulic pressure of 32co tons.

"The experiment thoroughly proved the union of the two parts, and is an excellent test of the merits of shrinkage without the interposition of any other metal."

Far from it! On the contrary, they are the evidences and practical results which aided the Gun Foundry and Fortifications Boards to make their valuable reports, and the Senate Committee on Ordnance and War Ships, in General Hawley's positive and comprehensive report, to present the following conclusions:

"All the guns in our Army and Navy, save the modern steel rifles ordered for the monitors and cruisers, are of classes whose manufacture is abandoned by the nations which have devoted themselves to perfecting cannon.

"The argument based upon the alleged economy of the cast-iron heavy rifle has been steadily losing force by reason of the constant cheapening of the processes of making gun steel, and the increasing ease of forging it in large masses.



SIR JOSEPH WHITWORTH'S EXPERIMENT SHOWING THE EFFECT OF SHRINKAGE.

"When a comparison is made between two guns giving an equal energy, it is found that the steel gun weighs but little more than half its competitor, and costs but little more. Such are the manifest uncertainties and weaknesses of the cast-iron gun, that the argument may be considered closed. This is the emphatic judgment of Europe, and in accepting that judgment this committee concurs with our own officers and experts.

"In every detail the advance of the last twenty-five years has been wonderful. The adoption of slow-burning powders, producing greater force with reduced strain, necessitated longer guns, whose use was made possible by breech-loading mechanism, bringing with it an increased rapidity and safety of loading. The attempts to make long rifles of cast iron, or of iron and steel, have been abandoned (and the value of wire-wound guns is still a question), since open-hearth steel and hydraulic forges have made comparatively easy the forging of 75-ton ingots of homogeneous steel exhibiting the highest qualities required for guns.

"The costly experiments of twenty-five years have reached a stage which justifies certain conclusions. Guns should be made of open-hearth steel, forged, breech-loading, chambered, of calibres ranging from five to sixteen inches, of lengths ranging from thirty to thirty-five calibres. Armor and projectiles should be made of forged steel. The hydraulic forging press produces better results than the steam hammer, costs much less, and should be used for Government work."

The objections that have so frequently been given by those individuals whose systems have been rejected—viz.: that military boards always exclude the ideas and inventions of the civilian that their own may be introduced and adopted—can have no pertinency in the consideration of the conclusions of the reports from which I have quoted, based as they were upon such a wide civil investigation; while the Fortifications Board, as you all know, had the benefit of the valuable services of the representative from Cambria, who has honored us with his presence to-night.

I have asked your consideration of these facts to emphasize the assertion that any attention paid to the wild theories of the iconoclasts, whose limited research and want of experience preclude a consciousness of their own ignorance, is not only an injustice to scientific students and practical men, but an impediment to the inauguration of that defense in which the whole country now believes.

Mr. Dorsey's skepticism in regard to the improvement of large

masses of gun steel by oil-treatment is endorsed by men of authority, and even so late as October last, by so prominent a one as the newly elected President of the British Iron and Steel Institute, Mr. Daniel Adamson, who, at the autumn meeting, expressed his want of confidence in "hardening in oil," even to "recommending the Government at once to consider, and to abandon it, if they came to the same conclusion that he had done—that the method was injurious at all times, and never desirable." He thus disputed the firm ground held by Professor Akerman, that "hardening in oil was a very important method for strengthening guns."

Mr. Vickers gave evidence that his experience of fifteen years was very much in favor of treating steel with oil; and a visit to his works in Sheffield would convince you all, not only of its utility, but that Mr. Vickers had many practical reasons for his endorsement of oil-treatment.

As early as 1863 we find prominence given to strengthening by oil-treatment. In the statement of Mr. Whitworth before the English Ordnance Committee, in advocating *built-up steel* guns, we find: "I go with Krupp, of Essen, the manufacturer of homogeneous metal. It is highly desirable it should be of right temper and properly manipulated." Since then its importance has greatly increased, and its use become more general. In fact, no gunmaker would be willing to take the responsibility of omitting it. In addition to gun, armor and projectile steel, shafts, hydraulic cylinders, rolls, rods, and other parts of machinery have been improved by oil-treatment, and the variety of its application is constantly increasing.

While the very general practice of oil-treatment has not reached a point where its results can be called *conclusive*, they are sufficiently definite to govern the most reliable manufacturers in their treatment of steel, and to enable them to produce very satisfactory results in large pieces.

It will be of interest to refer to a statement made last year by a member of the British Iron and Steel Institute, which was a public expression of the opinions held by many Englishmen: "During the last year or two some of our most prominent artillerists have been advocating the use of milder steel, both for the barrels and hoops of guns, than has previously been thought desirable, or than is necessary to pass the Government tests; and many of the guns now made for foreign governments are of a material the elastic limit of which is twenty-five tons, ultimate strength 33.9 tons per square inch, and

elongation twenty-nine per cent. in a length of two inches, when tempered at 1600° F. The subject of tempering and annealing is one which has not yet received, even at the hands of steelmakers, the attention of which I believe it to be worthy, and its methods of manufacture and working are therefore not so thoroughly understood as those of the softer steels, which are sent into the market in the form of boiler and ship plates, angles, bars, tees, girders, and other sections; and although any decided increase in the hardness of these things would, no doubt, lead to many serious difficulties, several eminent engineers have, during the last year or two, advocated the employment of steels of greater tensile strength for bridgebuilding and some other purposes than have hitherto been thought advisable. I think that most people will be ready to admit that the quality of the materials supplied for the construction of our weapons of war should be the highest possible, almost even regardless of cost, when so much may depend upon the safety and endurance of our guns, or on the power of their projectiles to penetrate the armor-clad forts or ships of an enemy."

If it be true that fair results can be obtained with "mild steel," though badly worked, this should be a powerful reason why it should be avoided, not only for heavy guns, but for every other purpose where certainty and reliability and strength are required. A pertinent remark in regard to this will be found in the *Army and Navy Register* of June 26 last, where, in an article on "Modern Artillery," reasons were given to account for the failures of English material. "The difficulty lies," says the writer, "in the fact that English manufacturers furnish the cheapest steel in the world; and in order to make cheap steel into guns it is necessary to lower the Government requirements of physical characteristics, temper, etc., to a point where no reliable gun can be made. The very best material must be used in the composition of the steel, or it will not stand the work that it is necessary to put into it to make it homogeneous; that material and that work must be paid for."

Is it, then, of such material as Mr. Dorsey advocates that military engineers should construct guns to sacrifice their country and their fellows? Is it to such material that military engineers are to yield, just as they have succeeded in securing a production from steel manufacturers who (after enormous expenditure) have reached a point where they can guarantee the uniformity and homogeneity, as well as the other requisites, of reliable gun metal?

Is it with such material that we are to invite similar failures (they will certainly come if we use the stuff he advocates) to those he condemns in England? I am sure no ordnance officer in either of our departments would think of advocating such a policy, and no one would dare do it, if he were required to stand by and fire his own guns.

An eminent artillerist said to me last summer, in Europe, that he had made unforged gun metal that, *theoretically*, was as strong as any forged steel he knew, and that he believed he could make a safe gun of it; but he did not believe it capable of such high ballistic power as forged steel ordnance was capable of obtaining; and, further, if he were Director-General of Artillery, he would consider it a criminal act on his part if he gave orders for its production and issue to the service.

I would like to add here that the vigorous attacks made during the past year in England have been upon the system of supply, poor material, bad design, individuals, conservatism, and absence of suitable, intelligent experiment. But nowhere in this prolific literature can there be found any demand for poorer, cheaper material to replace the characteristics that for so long have been too low instead of too high. On the contrary, one of the accusations of the English press called attention to the low characteristics, intimating that they were laid down for the special benefit of one firm, to be altered from time to time as that firm's production improved.

I do not agree entirely with the writer of the article on "Modern Artillery," from which I have quoted the above passage. As far as Sir Joseph Whitworth & Co. are concerned, it must be remembered that it is only within a limited period that this firm has received any orders for finished guns, and there is nowhere on record the bursting of any British gun manufactured of their material. In regard to design, I have some information which justifies me in saying that this firm's protest against the insertion of the liners in two parts in the guns under manufacture by them for the British Government caused the War Office to alter their designs in this important feature, at least as far as the contract with Sir Joseph Whitworth & Co. was concerned.

The steel we want for guns cannot be described by either of the terms "mild" or "hard" which Mr. Dorsey has employed. It must be *tough* and *elastic*, and manufactured with the greatest intelligence and care, from the selection of the charge to the finishing of the gun.

There must be nothing "*cheap*" about it, no uncertain or inadequate treatment. Such steel as we want exists abroad, and is fabricated into guns that have not and will not burst before a long life has been reached. It has already been made in small quantities in this country, and, as the demand increases, will soon be manufactured in larger masses.

In regard to the material of which the guns that have burst in England were made, it must not be forgotten that of the material in the Collingwood gun, the committee said there was a want of uniformity and proper treatment. My inquiries of the Chairman of Krupp's administration brought forth an absolute denial of the statement of Colonel Hennebert relating to the disabling of German guns at the siege of Paris, afterwards quoted by the Duke of Cambridge. But even admitting that thirty-six German guns were disabled, the result of the struggle between the two powers was sufficiently definite to point out what splendid work the remaining ones accomplished.

The failures to which Mr. Dorsey has referred prove that *poor* steel of any physical characteristics is no more fit for guns than was the inferior steel for their purposes that the civil engineers used for structures, and which reflected so seriously, but falsely, upon the use of steel as a superior material to iron. I claim that the failures of the steel guns in England (I suppose them to be the ones to which Mr. Dorsey refers) resulted from causes entirely distinct from those that he imagines them to be. By no journal has this matter been more thoroughly and ably handled than by the London *Engineering*. This paper, edited by men of high technical ability, is an advocate of the opinions and work of a large number of British mechanicians. As you all know, and have probably read, there have appeared exhaustive reviews of the sad condition of England's gun supply. Severe as these attacks have been upon administration and methods, all the articles have demanded more powerful ordnance and better material.

I believe that Captain Michaelis, of the Ordnance Corps of the Army, is the only military engineer who quotes the essayist to any great extent; while in the Navy there also remains one isolated example, who has stated that he is "firmly convinced that the gun of the future, both for seacoast and afloat, will be a *steel-cast gun.*" Against the opinions of such names as Dorsey, Michaelis, Metcalf, Thurston, Howe, Evans, William P. Hunt, Haskell and Wiard (who advocate cheap material of one kind or another), I feel myself on very

solid ground in accepting the work of Whitworth, Schneider, Krupp, Vavasseur, Kolokoltzoff, Simpson, Fritz, Leavitt, Joseph Morgan, Jr., Davenport, and Birnie, and hope I may be allowed the benefits of their advice and guidance for many years yet to come. If the former are content to remain where Rodman brought the ordnance problems, the latter are not; and I am confident, were General Rodman alive to-day, he would be as firm an advocate of forged, oil-treated steel of high physical characteristics as either Krupp, or Whitworth, or Schneider. I look upon the persistent attempts to keep gun construction where Rodman left it, which have had so much influence in blocking progress in the Army, as a reproach to his memory and to his attainments.

Sometimes the minority is right, but there appears to be no chance for it in this case; for if forged steel built-up guns are not the best, there has been ample time since 1843 to discover the mistake. Instead, however, of there being a shadow of a doubt as to their superiority, every power on the face of the fighting earth has accepted a steel of the characteristics Mr. Dorsey condemns. Mr. Hewitt's answer to an advocate of cast-iron ordnance—"Of course you are aware that you have the judgment of every military engineer against you"—applies well to the essayist's theories; and, further, not only is the judgment of every military engineer against them, but there is added thereto the weighty judgment of the most eminent steel manufacturers of the land, the majority of whom, I am informed, have not only not been consulted by the essayist, but have never even heard of him.

Before closing I desire to call the attention of all the members of the Institute to the pleasure I have had, during my recent visits to Europe, to hear on every side such honorable mention of the work this Institute has done, and the esteem with which our worthy President, Admiral Simpson, is held by the military scientists of the Old World as well as the New.

These facts, added to the honor and merit that have been conferred in complimentary notices by the foreign press, should be most gratifying incentives for its further development.

Professor CHAS. E. GREENE, *University of Michigan, Ann Arbor, Michigan.*

Material, to successfully withstand great shocks repeated a number of times, ought to have a large capacity for absorbing energy. This

capacity will be measured by the product of two quantities—deformation, and the mean resistance overcome in producing the deformation. The best material; therefore, will be, not that which has the highest ultimate or breaking strength, nor that which has the greatest ductility or deformation under a given stress, but that material or grade for which the product of these factors is a maximum.

A careful reading of published results of experiments on different grades of steel and of actual work leads one to conclude that high steel, while possessing great tensile strength, is deficient in ductility, or is brittle. Toughness is what is wanted. It also appears that the requirements of the Ordnance Office of the War Department that the steel for hoops for 8-inch guns shall have a tensile strength of not less than 100,000 pounds per square inch, with an elongation after rupture of not less than twelve per cent. in six inches, embody two limits which are likely to be incompatible; that is, 100,000 pound steel will not have that amount of stretch, and steel of that ductility will have a less tensile strength.

The points which Mr. Dorsey has emphasized in his paper are well taken, and I agree with him in his opinion of hard and mild steel.

FRANCIS COLLINGWOOD, C. E., *Assistant Engineer during Construction of New York and Brooklyn Bridge.*

Your communication, with request for discussion of Mr. Dorsey's paper, reached me in due time. I have delayed replying in hopes that I might find time to write briefly my views, but am altogether too busy just at present to do so. I do not think, however, that I could add anything to what I have said already in a discussion on Mr. Schneider's paper on the Niagara Cantilever Bridge, which you will find on page 577, etc., of the *Transactions of the American Society of Civil Engineers* for 1885.

My attention has been turned chiefly to the proper material for bridges and similar structures, such as will test in unworked specimens at about 70,000 pounds, or when drawn into wire of one-eighth inch diameter at about 150,000 pounds. The great difficulty of securing uniformity of state in large masses, when higher grades are used, resulting in unknown internal strains which cannot be guarded against, is a strong argument against their use. In these days of improvement and the rapid advances that are making in all metallurgical operations, it will not do to say that such difficulties will not

disappear. I am inclined to think, however, that they still exist at the present.

The discussion I mention summarizes the methods of tests and requirements extant abroad at the time of a visit made there in 1884.

HIRAM S. MAXIM, C. E., *The Maxim Gun Company, London, Eng.*

Highly carbureted steel, or hard steel, is unquestionably more apt to break and much more unreliable than soft steel, especially in large pieces. Any one who has worked this kind of steel knows that every cut taken from it changes its shape. If a large piece be placed on a planer and a heavy cut be taken from one side, the piece warps; in fact, every time a cut is taken from any portion of it the whole mass seems to warp and twist. This is due to the fact that there is not a state of molecular rest in the mass.

If a large block of this hard steel should be cut into a number of strips, it would be found that no two of them, after cutting apart, would be exactly the same length: some would be longer and others shorter than the block from which they were cut.

I do not regard tempering in oil, as conducted in England, to be beneficial to the tubes of large guns.

The experts who constituted the committee of inquiry in the Collingwood gun have given for a reason that the tube burst because it was not annealed after it was tempered. The annealing, to my mind, would place the tube in exactly the same condition that it was before it was tempered at all; in other words, the effect of tempering would be completely removed by annealing. If a large forging of steel be cooled from the outside, the outside becomes hard and incompressible while the inside is still very hot. Now, when the inside comes to cool, it shrinks, and as it cannot shrink away from the outside, it is put in a high state of tension; while the outside by being drawn inward, is put in a high state of circumferential compression. If the steel be of hard quality, cracks may form in the interior. At the instant these cracks form a loud click is heard, so that faults of this kind are technically called "clicks" at the steel-works. They may be either longitudinal or transverse clicks.

All British guns are made of steel which is sufficiently carbureted to be susceptible of being tempered; the fact is, this steel may be made quite hard if tempered like ordinary steel. I myself have made very fair drills of it. The tube of the Collingwood gun was tempered

from the outside, and of course, the outside becoming cooled before the inside, the outside was put in a state of compression, the exact reverse from what it should have been to stand internal pressure.

Before firing, the outside of this gun was attempting to pull the inside asunder, and only required the assistance of a moderate internal pressure to start the crack. If the tube had been cooled from the inside, the exact reverse would have been the case, the inside being in a state of compression and the outside in a state of tension. The first would have been improved by annealing, and the latter injured for the purposes of a gun.

With a low grade of steel, however, these differences in tension are not set up in the same degree; to be sure, the steel is much weaker, but all its particles pull in the same direction. It is not a house divided against itself.

I have lately had quite a controversy with some gun experts. I have taken the ground that the guns burst because they were cooled from the outside instead of from the inside. I made numerous diagrams to show the molecular strains set up in steel when tempered from the outside and when tempered from the inside, and have tried to point out that tempering from the outside was worse than no tempering at all.

I was at first strongly combated, but by persistence, and by making the matter very plain, I in the end succeeded in convincing them all that I was right.

In conclusion, I would say, if in the use of hard and strong steel it is not possible to make all of the particles pull together, then by all means make guns of soft steel.

ROBERT W. HUNT, *General Superintendent Troy Steel and Iron Company.*

*Gentlemen of the Institute:*—In response to your invitation to discuss Mr. Dorsey's paper on "Steel for Heavy Guns," I will offer but a few brief remarks, based on my experience as a maker and user of steel.

It is hardly necessary for me to state that I have not had experience in making steel for heavy guns, and that my knowledge of its behavior in such form is based entirely upon report. But I have encountered, and often in disagreeable professional ways, the treacherous, or perhaps it would be better to call it unlooked-for, behavior

of high steels in parts of machinery. As stated by Mr. Dorsey, every establishment in which large pieces of high steel have been used has its story of many unexpected failures. That such failures should occur is easily understood and fully explained by the well-established fact that the change of volume due to heat increases with the quantity of carbon in the steel, which must of course make metal with a high percentage of that element more liable to internal strains than a low-carbon steel. As the carbon increases, so does the danger. To guard against this, all depends upon the care exercised in the forging and annealing. Should any one fail in this care, or the use of proper judgment, the disastrous result in the case of a gun would only be known after much money had been expended, and when its loss would be the smallest part of the calamity.

Soft steels are made by many well-established firms, and with as great uniformity as belongs to any large manufacture. Of course, for so particular a purpose as the manufacture of ordnance, the *best stock* would have to be used and the greatest skill exercised in making the steel; but the risk of failure would approach zero, as compared to high steels, and such heats or charges that should fail to stand the required physical tests could be applied to ordinary commercial purposes without loss to the maker, and for which the metal would be well adapted. Then, after the steel was made, the risk of ruining it in subsequent manipulations would also be reduced to the minimum.

If I mistake not, the experience of the United States Ordnance Corps has demonstrated that soft steel is the proper metal for the construction of field-gun carriages. And you will permit me to give the physical test of the steel from which the successful carriage was constructed. The specimen was twenty inches long, two and a half inches wide at shoulders, seven and a half inches between shoulders, and 0.254 inches thick. Upon the Watertown testing machine it gave per square inch 70,990 pounds tensile strength; 27.4 per cent. elongation; 52,460 pounds elastic limit, and 44.8 per cent. contraction of area. Its carbon was 0.17 per cent., and it broke with a silky fracture. It seems to me that such metal would be the grade to use in the construction of heavy guns, if they are to be made from forged pieces. But why should the authorities so persistently decline to investigate the merits of *cast-steel* guns? The investigation would cost but little, and I am sustained by the opinion of many able steel-makers in believing in that form of manufacture we will find the

cheapest and best guns. There are American works ready now to make the trial, and if successful, the requirements of the country can be rapidly met, and without asking any one to risk some millions of dollars in the construction and capitalization of a plant which may prove a failure. We have plants capable of casting the gun or guns, and the Government has at South Boston tools *now ready* to finish them. Fifty thousand dollars would afford an ample fund.

Mr. T. F. ROWLAND, *Proprietor Continental Works, Greenpoint, N. Y.*

Under date of December 9, 1886, I had the honor to receive from the Institute a copy of a paper by Edward Bates Dorsey, C. E., entitled "Steel for Heavy Guns," which paper will be read at a meeting of the Institute on the 5th inst., upon which occasion, as it is impracticable for me to be present, I am invited to express my opinion and criticism of the paper in writing. In response to said request, I have carefully read Mr. Dorsey's paper, and I beg to say I heartily agree with the statements and conclusions therein contained.

Having been more or less engaged for the last fifteen years in the working of Siemens-Martin and Bessemer steel plates, welding the same into various forms, such as cylinders for boilers, cylindrical vessels to contain excessive pressures, notably liquid carbonic-acid receivers, torpedo cases, etc., I long ago discovered that steel much exceeding sixty-five thousand pounds (65,000) T. S. was treacherous and unreliable to the last degree, whereas steel of not more than sixty-three thousand pounds (63,000), or less than fifty-five thousand pounds (55,000), preferably the average, could be wrought and welded into any shape with full assurance as to the results.

In 1880 I took an order to furnish a number of welded-steel receivers, which were to be sent to Russia to be incorporated in the "Lay Patent Torpedoes" then being built for that Government. These receivers were intended to contain the liquid carbonic acid used to produce the torpedo motive power. The method of construction was the rolling and welding into cylindrical forms, twenty-four inches in diameter and four feet long, sheets of Siemens-Martin steel half inch thick, into the ends of which suitable steel heads were welded. The tensile strength of the steel of two of these cylinders, as stated by the Naylor Steel Works, of Boston, who manufactured the plates, was ninety thousand pounds (90,000); the other plates were stated as of sixty thousand pounds (60,000).

The receivers made of the 90,000-pound metal burst under hydrostatic pressure of fifteen hundred pounds (1500) per square inch, which was equal to thirty-six thousand pounds (36,000) strain per square inch of metal. Pieces of the steel broke out as if the receiver had been made of cast iron. The receivers made of the sixty thousand pounds T. S. (60,000) metal were tested to seventeen hundred pounds (1700) per square inch (hydrostatically), or to a tensile strain of forty thousand eight hundred pounds (40,800) per square inch of metal, and withstood it without any damage to the material. Since then I have made it a rule to purchase no steel of over sixty-five thousand pounds (65,000) T. S.

I have lately manufactured one hundred and fifty (150) welded-steel (55,000 pounds T. S.) cylinders six feet four inches diameter, thirty inches long, quarter inch thick, with two-inch external flange turned upon each end, which flange I have turned cold in a machine provided for the purpose, a feat which would have been impossible of accomplishment had the metal possessed a high degree of tensile strength.

I fully agree with Mr. Dorsey in his statement that steel of a given tensile strength varies in reliability and value as its thickness, the maximum approaching where the metal is thinnest; and I believe that what he designates as "*mild*" is a more suitable metal for the construction of guns than the quality he designates as "*hard.*"

True, the latter has a greater theoretical value, but it cannot be depended upon, while the former can be.

In the manufacture of guns, it would seem that a number of thin hoops or cylinders constructed of metal whose value is known and is reliable, would be much preferable to one hoop or cylinder equal in thickness to all the others, and whose value, though theoretically known, is, in practice, utterly unreliable.

In conclusion, I beg to reiterate that my convictions upon the matter in question are in full accord with the statements made in Mr. Dorsey's paper. It is a valuable document, and he well deserves the thanks of all workers in steel for having brought the question before the Institute, where it will doubtless receive proper discussion.

Very respectfully, THOS. F. ROWLAND.

C. C. SCHNEIDER, C. E., *New York.*

The experience of bridge engineers confirms Mr. Dorsey's opinion that steel having an ultimate strength of over 100,000 pounds per

square inch is unreliable and unfit for structural purposes. The treacherous qualities of hard steel, owing to its crystalline nature, are well known to all workers in that metal. If used for parts of structures not exposed to external injuries, mild steel of from 60,000 to 70,000 pounds ultimate strength, which has been carefully worked, I consider just as reliable as the best wrought iron, besides having the advantage of greater strength. If it were possible to combine the fibrous nature of wrought iron with the high ultimate strength of steel, we would have the most suitable and reliable material for structural purposes; and, in my opinion, this would also make an excellent material for heavy guns. The nearest approach to this is wire rope made of good steel.

For the sake of economy, I deem it advisable for our Government, before spending many millions of dollars on new guns, whose efficiency in actual service is doubtful, to have this subject thoroughly investigated by a series of careful experiments conducted under the supervision of able and experienced men.

Mr. JAMES CHRISTIE, C. E., *Philadelphia, Pa.*:—I am not sufficiently acquainted with the reasons that have influenced the choice of the grade of steel specified to hastily condemn the action. Not only high tension, but also the power to resist erosion must be considered, and no doubt the latter power is increased by tempering the finished material.

I agree with Mr. Dorsey, and think that common experience will justify his assertion that for purposes where severe shock or suddenly applied or accelerated strains are applied, hard steel is not an entirely trustworthy material; and more especially is this true when rapid changes of temperature are involved.

But while this "capricious" property, as it is termed by Mr. Dorsey, is more apparent in the hard steel, I cannot agree with him that it is entirely absent in the extremely mild and ductile steels.

Steel of any grade is affected to a marked extent, as compared with the best wrought iron, by disturbance of its surface, in this respect bearing some analogy to the behavior of glass when scratched by the diamond.

I have repeatedly seen steel cracked by the drop test with a facility that, under similar circumstances, would have ensured the condemnation of wrought iron, and from no greater cause than a scratch skin-deep around the body. I acknowledge that this weakness is more

evident in the high-tension steels, but it is also found in steel of the lowest tension and highest ductility, and in metal which previous to being scratched seemed capable of enduring an astonishing amount of torture. Steel is peculiarly liable to surface abrasion if both rubbing surfaces are soft and not thoroughly protected by some lubricant. The tempering process affords great relief from this tendency to abrasion, and no doubt in the case of steel guns would give increased resistance to the destructive effect of interior erosion.

In the case of mild steel that will not take any perceptible temper by cooling from red heat, it has been found a marked advantage, in resisting abrasion, to case-harden the surface by the methods usually practised with iron.

A marked improvement in the strength and endurance of steel has been abundantly proved by compacting the metal by the forging process. In the absence of any experience on the subject of steel for ordnance, I would be led to believe, on general principles, that the best results would be attained by the use of the most ductile metal, even if its tensile strength were the minimum, for the body or strength-giving part of the gun. The chamber might be case-hardened on its interior surface, or, if this should prove impracticable, a harder steel, oil-tempered, might be used. The whole subject is worthy of the careful consideration of the authorities before committing themselves to the use of any particular grade of steel.

PENNSYLVANIA RAILROAD CO.: MOTIVE POWER DEP'T.
ALTOONA, PA., *December* 27, 1886.

EDWARD BATES DORSEY, Esq.

*Dear Sir:*—Referring to yours of December 21st, in regard to steel for heavy guns, I have read over your paper with very much interest, and may say that in general I agree entirely with the conclusions which you have reached. In my judgment, no more serious error has been made in later years by engineers everywhere than the attempt to use steel of 80,000, 90,000 or 100,000 pounds tensile strength in constructions.

We have had considerable experience on the Pennsylvania Railroad with such steels, and have uniformly found them unsatisfactory.

If possible, I shall be at the discussion on January 5. I am a little afraid, however, that I may not succeed, and lest I should not be there, I will say that although I might not agree to everything said in

your paper, I fully agree with the main conclusion—that it would be best to use mild steel for heavy guns.

Very truly yours,

CHAS. B. DUDLEY, *Chemist.*

WASHINGTON, D. C., *January* 4, 1887.

SECRETARY U. S. NAVAL INSTITUTE, *Annapolis, Md.*

*Dear Sir* :—In the matter of the use of high-grade steel for guns and other structures subject to variable strains, I have been obliged to make considerable study as Chairman of the Committee on Military Affairs of the 48th Congress, which committee was compelled to go into some investigation, and has made a report with the testimony taken, which has been printed.

I regret that I cannot forward a copy of the same to the Naval Institute; but the outcome of all I know in the matter is thoroughly confirmatory of the views taken by E. B. Dorsey in his paper, copies of which I have had to thank you for.

Had I time, I would formulate my conclusions on the subject, with reasons therefor. Failing that, I desire to state, as above, my conclusions.

Very truly yours,

W. S. ROSECRANS.

CRESCENT STEEL WORKS: MILLER, METCALF & PARKER.

PITTSBURGH, *December* 9, 1886.

EDWARD BATES DORSEY, Esq.,

127 *East 23d St., New York.*

*Dear Sir* :—I object decidedly to your statement that the cracking and breaking of high steel is " mysterious and unaccountable."

There is no mystery about it. High steel is a truly crystalline substance, like glass, and obeying the same laws.

Langley showed, years ago, that high steel increased in volume per degree of temperature very much more than mild steel, by taking the specific gravities of different grades of steel under the same conditions of treatment. See chapter " Why Does Steel Harden?" in "Treatment of Steel." This increase of bulk, when not perfectly uniform in the mass, sets up injurious internal strains in high steel, sometimes breaking the piece in manipulation, sometimes leaving it in a state of unstable equilibrium for subsequent failure. That is all there is of the mystery.

It is certain that high steel cannot be forged in large masses, nor pressed, nor worked in any way so as to be practically safe.

Oil-tempering strengthens all steel; so does water-tempering; so does quick cooling in any manner. It is always a dangerous operation, the danger increasing with the size in geometrical progression, and with the hardness of the steel the danger ratio is much greater. Wade and Rodman proved, many years ago, that quick cooling increased the strength of cast iron, but neither of them ever tried to make a chilled cast-iron gun. Engineers are all looking in the wrong direction in studying steel; they are studying modes of cooling, forging, tempering, etc., when in fact the properties are all given and varied by heat.

The heat in melting, the heat in pouring, the rate of cooling, and the heat at which to anneal—these are the controlling manipulations, and they are also the easiest to control.

Your thin-hoop guns and the wire guns lead out to the true theory—that is, to have an infinite number of hoops or wires acting radially, tangentially, and along the axis. These can be obtained by casting, cooling and annealing.

The annealing can be repeated as often as necessary, the cooling can be controlled in the desired direction, and the whole operation would be sure, safe and cheap. Yours very truly,

WM. METCALF.

THEO. N. ELY, *General Superintendent of Motive Power Pennsylvania Railroad Company*:—Probably I cannot add much of value to what has already been written and said, but wish to express myself as in entire sympathy with the general conclusions reached by Mr. Dorsey in the paper which you forwarded, agreeing as they do so well with the experience which we have had during the last twenty-five years in the use of steel for boilers and fire boxes, as well as that used for car axles and a number of the parts of locomotives, such as tires, crank pins, etc.

The enclosed printed specifications will indicate more clearly what the practice of the Pennsylvania Railroad Company is in the purchase of steel.

Some years since, in order to strengthen some iron bridges the design of which did not admit of tension rods of larger diameter, steel was substituted for the iron rods; but the results were not satisfactory, as the steel was too high, and in the endeavor of the nuts to adapt themselves to the surfaces against which they were pressed, fracture at the thread was soon developed.

That part of Mr. Dorsey's paper which refers to the danger of ruptures occurring in steel, induced by dints or abrasion, is worthy of careful consideration.

Recognizing the dangers of a final rupture, due to incipient cracks or imperfections, it has been the custom of this company for some years to have the steel axles used under passenger-equipment cars rough-turned throughout their length ; the higher the steel, the more liable it is to crack.

This property of steel we speak of as "breaking in detail"; this is very well illustrated by a piece cut from the journal of an axle which broke in this manner.

I have never known steel axles to break in any other way. The starting of this fracture is possibly due to the journal having been cut by some foreign substance.

In conclusion, I would say that when steel is used we endeavor to keep it as mild as possible, in many cases increasing the size to obtain the stiffness necessary, rather than to use steel of higher grade. Of course we are sometimes limited in this respect, and have to use a little higher steel than we consider the proper grade.

This letter has been hastily composed, but you are at liberty to use it in any way you may deem proper.

## SPECIFICATIONS FOR CRANK PINS.

All specifications for crank-pin steel heretofore issued are hereby annulled and superseded by the following :

Steel ingots for crank pins must be swaged as per drawings.

For each lot of fifty ingots ordered, fifty-one must be furnished, from which one will be taken at random, and two (2) pieces, with test sections five-eighths inch diameter and two inches long, will be cut from any part of it, provided that centre line of test pieces falls one and one-half inches from centre line of ingot. Such test pieces should have a tensile strength of 85,000 pounds per square inch, and an elongation of fifteen per cent. Ingots will not be accepted if the tensile strength is less than 80,000 pounds, nor if the elongation is below twelve per cent.*

## SPECIFICATIONS FOR STEEL BILLETS FOR MAIN AND PARALLEL RODS.

One billet from each lot of twenty-five billets or smaller shipments of steel for main or parallel rods for locomotives will have a piece drawn from it under the hammer, and a test section will be turned down on this piece to five-eighths inch in diameter and two inches long. Such test piece should show a tensile strength of 85,000 pounds and an elongation of fifteen per cent.

* Stiffness desired. Size cannot be increased.

No lot will be acceptable if the test shows less than 80,000 pounds tensile strength, or twelve per cent. elongation in two inches.*

## SPECIFICATIONS FOR PLATE AND SHEET IRON AND STEEL.

All iron and steel plate other than boiler, fire-box and tank-steel plate, and all sheet iron and steel, whether black, galvanized or planished, will be designated on orders as "No. 1," "No. 2" or "No. 3," to show what quality is wanted, and materials furnished on such orders must be of such quality as will meet the requirements of the following specifications for the material ordered, which will supersede the specifications for sheet iron dated March 2, 1883.

### No. 1.—Plate and Sheet Iron and Steel.

No. 1 plate and sheet iron and steel must be of a grade that is suitable for flanging and edging with and across fibre, such as plate for track tanks and tank heads; sheet, black or galvanized, for the most difficult parts of head-lights, canopies, linings, casings, ventilators, hoods, buckets, elbows, spouting and passenger-car roofs; planished sheet for boiler-jacket collars.

No. 1 plate one-eighth inch thick or over must have a tensile strength of not less than 48,000 pounds nor more than 60,000 pounds, and an elongation of twenty per cent. in section two inches long, and the thinner forms of sheet metal must stand the working as prescribed above without cracking.

### No. 2.—Plate and Sheet Iron and Steel.

No. 2 plate and sheet iron and steel must be of a grade that is suitable for flanging when the line of the flange runs across the fibre, such as black or galvanized sheet for freight-car roofs, locomotive smoke stacks and wheel covers; planished sheet for the main portion of boiler jackets.

No. 2 plate one-eighth inch thick or over must have a tensile strength of not less than 45,000 pounds nor more than 55,000 pounds, and an elongation of fifteen per cent. in section two inches long, and the thinner forms of sheet metal must stand the working as prescribed above without cracking.

### No. 3.—Plate and Sheet Iron and Steel.

No. 3 plate and sheet iron and steel must be of a grade suitable for rolling and riveting, and must stand punching for use in flat sheets and rolling into cylindrical form, such as smoke jacks and plain cylindrical casings.

No. 3 plate one-eighth inch thick or over must have a tensile strength of not less than 42,000 pounds nor more than 55,000 pounds, and an elongation of ten per cent. in section two inches long.

## SPECIFICATIONS FOR AXLES.

Car axles and locomotive-tender and truck axles will be ordered subject to the following conditions, which annul all previous requirements:

For each 100 axles ordered, 101 must be furnished, from which one will be taken at random, and subjected to tests prescribed for such axles. If the axle stands the prescribed test, the 100 axles will be carefully inspected, and those

* Stiffness and lightness desired.

only will be accepted which are made and finished in a workmanlike manner, and which are free from cracks or unwelded seams.

Locomotive-tender and car axles to have journals swaged, and all axles to be centred with 60-degree centres.

### Passenger-Car and Passenger-Locomotive and Tender-Truck Axles.

Axles must be made of steel and be rough-turned throughout.

Two test pieces will be cut from an axle, and the test sections of five-eighths inch diameter by two inches long may fall at any part of the axle, provided that the centre line of the test section is one inch from the centre line of the axle. Such test pieces should have a tensile strength of 80,000 pounds per square inch, and an elongation of twenty per cent. Axles will not be accepted if the tensile strength is less than 75,000 pounds, nor the elongation below fifteen per cent., nor if the fractures are irregular.

### Freight-Car and Freight-Locomotive and Tender-Truck Axles.

Steel.—Steel axles for freight cars, and freight-locomotive, and tender trucks, will be subjected to the following test, which they must stand without fracture:

*Axles Four Inches Diameter at Centre.*—Five (5) blows at twenty feet of a 1640-pounds weight, striking midway between supports three feet apart; axle to be turned over after each blow.

*Axles Four and Three-Eighths Inches Diameter at Centre.*—Five (5) blows at twenty five feet of a 1640-pounds weight, striking midway between supports three feet apart; axle to be turned over after each blow.

Iron.—Iron axles for freight cars, and freight locomotives, and tender trucks, are to be hammered; new muck bar must be used, which must be thoroughly reworked at least once before piling for the axle; it must be tough, fibrous, uniform, and free from scrap. If reworked by rolling, the slabs must not be greater than three-quarters inch thick when piled for the axle; if reworked by hammering, the power of the hammer must be sufficient to work the pile to its centre to the satisfaction of the P. R. R. Inspector. Such axles will be subjected to the following test, which they must stand without fracture:

*Axles Four Inches Diameter at Centre.*—Three (3) blows at ten feet and two (2) blows at fifteen feet of a 1640-pounds weight, striking midway between supports three feet apart; axle to be turned over after each blow.

*Axles Four and Three Eighths Inches Diameter at Centre.*—Three (3) blows at twelve feet and two (2) blows at eighteen feet of a 1640-pounds weight, striking midway between supports three feet apart; axle to be turned over after each blow.

## SPECIFICATIONS FOR TANK STEEL.

All tank steel will be ordered subject to the following specifications:

1st. No sheet will be received that shows mechanical defects.

[illegible]est strip from each sheet, taken lengthwise of the sheet, and without [illegible] should have a tensile strength of 60,000 pounds per square inch and [illegible]n of twenty five per cent. in a section originally two inches long.

3d. Sheets will not be accepted if the test shows a tensile strength less than 55,000 pounds or greater than 70,000 pounds per square inch, nor if the elongation falls below twenty per cent.

4th. Manufacturers must send one test strip for each sheet (this strip must accompany the sheet in every case); both sheet and strip being properly stamped with the marks designated by this company, and also lettered with white lead to facilitate matching.

## SPECIFICATIONS FOR BOILER AND FIRE-BOX STEEL.

All specifications for boiler and fire-box steel heretofore issued are hereby annulled, and superseded by the following:

1st. A careful examination will be made of every sheet, and none will be received that show mechanical defects.

2d. A test strip from each sheet, taken lengthwise of the sheet, and without annealing, should have a tensile strength of 55,000 pounds per square inch, and an elongation of thirty per cent. in section, originally two inches long.

3d. Sheets will not be accepted if the test shows a tensile strength less than 50,000 pounds or greater than 65,000 pounds per square inch, nor if the elongation falls below twenty-five per cent.

4th. Should any sheets develop defects in working, they will be rejected.

5th. Manufacturers must send one test trip for each sheet (this strip must accompany the sheet in every case); both sheet and strip being properly stamped with the marks designated by this company, and also lettered with white lead to facilitate matching.

THEO. N. ELY,
*General Superintendent Motive Power.*

## Captain O. E. MICHAELIS, *Ordnance Department U. S. A.*

Mr. Dorsey has succinctly stated the advantages of mild steel for ordnance purposes, and in doing so he has reflected the views of the most prominent steel experts of the day. As an engineer, appealing to a technical audience, he has apparently not deemed it necessary to fortify his correct conclusions by adducing well-known data; in this he has wisely trusted to the knowledge of his hearers. Still, it may not be out of place to state a few pertinent facts, the correctness of which is unimpeachable. Mr. George Ede, of the Royal Gun Factories Department, Woolwich Arsenal, in his little work, "The Management of Steel," though issued in 1867, yet in 1884 quoted as "valuable" by Mr. William Metcalf, unquestionably, since Holley's death, our most prominent scientific and practical steel expert, in addressing those "who are more attentive to authority than reason, and who inquire by whom a process is used rather than what are its merits," states that the toughening of large masses of mild cast-steel

blocks and tubes is in daily practice at Woolwich. After describing in detail the process of cooling the steel in oil, Mr. Ede adds: "Exceeding toughness is the result of the operation, while it is thus made much higher in tensile strength, offering a much greater resistance to compression. It is also harder and more elastic, and requires a much greater force to break it under the hammer, and it is not worn or indented so readily as when received from the tilt or annealed. . . . . . . Steel containing much carbon oil will harden the surface very much more than its internal parts, so that it will resist the file; but beneath the surface it will be quite soft. In steel containing a less proportion of carbon there appears to be very little difference between its external and its internal parts. In theory there cannot be much difference between the external and the internal parts of steel containing such a small amount of carbon and not possessed of hardening properties, or only in a slight degree; and in practice the theory is proved to be correct." Again, in reply to a supposititious question, this practical steel-ordnance expert says: "It may, perhaps, be asked by those who are not practically acquainted with the hardening and tempering of steel, if it would not be better to make a solid shot entirely of highly carbonized blister, shear or cast steel, and subsequently harden and temper it. The answer is, thick lumps of highly carbonized steel, whether hardened in oil or pure water, or water with a film of oil upon its surface, cannot be hardened without becoming fractured either internally or externally." The exhaustive series of experiments carried on for a period of five years by Professor John W. Langley, Professor of Chemistry, University of Michigan, and Mr. William Metcalf, of Pittsburgh, are authoritative; the results were presented to the American Association for the Advancement of Science by Professor Langley, and to the American Institute of Mining Engineers by Mr. Metcalf, and are familiar to all interested in the subject. These experiments were undertaken to obtain commercial information, without any reference whatever to gun construction, and hence are certainly free from even the slightest taint of "bias." The following general laws were indicated by these experiments:

I. The specific gravity of the steel ingot varies directly with the quantity of iron present.

II. The greater the quantity of carbon present, the greater the amount of work necessary to produce change of form.

III. The greater the quantity of carbon present, the greater is the : in volume due to a change of temperature.

Upon this last deduction Mr. Metcalf makes this comment: "This is perhaps the most important observation that can be made on this series of experiments, as it shows us why it is that high steel is so much more liable to crack and break in manipulation than low steel. We generally say one is brittle and the other is ductile; we now know that the rate of expansion per degree of temperature is much less in low steel than in high steel. Therefore, low steel is much less liable to injurious internal strains than high steel." Another conclusion from these experiments has a very important bearing upon the question under discussion: "If steel of moderately high carbon be repeatedly hardened, it will continue to increase in volume until ruptured." I believe that this explains the reported failures, without apparent cause, of many high-steel guns. Professor Langley has demonstrated that sudden cooling from even a boiling temperature causes a hardening effect. Do we not approximate this condition in firing guns—especially where a wet sponge is used? It seems to me that this successive hardening, with its accompanying increase of volume, may in time carry the tension members of the built-up gun beyond their elastic limit, and rupture ensues under slight provocation. We must bear in mind that the slow cooling of a steel gun after firing is virtually an annealing process, and that thereafter, under favorable conditions, it is again prepared for the hardening process, a not improbable concomitant of battle use. In this connection, I will cite a result reached by Mr. L. L. Buck, the engineer in charge of the renewal of the suspended superstructure of the Niagara Railway Suspension Bridge, in his test of the steel he proposed to use, which is of some service to us interested in gun construction. Mr. Buck desired to ascertain the capacity of specimens, running as high as .48 carbon, having an ultimate strength running over 100,000 pounds, with a stretch of less than eight per cent. in ten inches, for *resisting shocks.* His conclusion, from his elaborate and careful investigation, though *aliunde* as concerned his immediate subject, was that "high steel, if used in structures where the dead load considerably exceeded the live load (in the case of the tensile members), might be perfectly reliable, while in case the dead load was small and the live load large in proportion, it would be dangerous."

The application is obvious. It cannot be doubted that high steel, as already explained, is more liable to dangerous internal strains than low steel; and I am convinced that these latent forces, imprisoned in

the finished product by "cobweb" chains, easily swept away by favoring circumstances, explain the mysterious casualties so frequently reported. Some of these masses are veritable Prince Rupert drops, in apparent equilibrium, solid and strong, but on application of the proper slight disturbing element they crumble into dust. At the Annual Convention of the American Society of Civil Engineers, Buffalo, June 10, 1884, I read a paper (copy enclosed) on "The Heavy-Gun Question" (*Transactions*, Vol. 13: July, 1884). I advocated the trial of a hollow-cast, open-hearth steel gun, and subsequent study of the subject has strengthened my belief in the entire practicability of this method of gun construction. By the expenditure of one-quarter of one per cent. of the amount necessary for our efficient armament a final, present test can be encompassed; if decisively successful, at least half a dozen large plants would at once enter upon the casting of the heaviest guns, which could be furnished with a fair profit at two hundred dollars per ton. The most recent investigations have shown that in order to obtain the greatest chemical homogeneity, the very soul of modern structural steel, in hollow or annular forms, the largest possible cores should be used, and the mass cooled from within—a condition fully met by the Rodman process. The anticipated difficulty of mould-instability, penetrating sand-patches and so forth, need no longer be feared, for I can bear witness, after personal examination, that Mr. Hemphill's sheet-iron casing is an almost certain remedy. We have to-day at Cleveland a sufficient furnace capacity to turn out the required casting, and at South Boston an adequate machining plant. For our open-hearth bath we have available a pig metal, free from silicon and manganese, carrying no sulphur at all, and guaranteed to be below the point .015 in phosphorus; this, with the best charcoal blooms for softening, including ferro-manganese and ferro-silicon additions, would bring up the cost of the melt in the ladle to about $70 to $75 per ton—high, but not excessive for the grade. Is not the time ripe for the trial of a method seconded by almost all the prominent steel experts in the country? Washington, in his Annual Message, January 8, 1790, says: "The safety and interest of the people require that they promote such manufactures as tend to render them independent of others for essential, particularly for military, supplies." Should the casting of steel guns be successful, Washington's charge would be effectually carried out, for soon—very soon—every large steel plant in the country would have capacity for turning out the heaviest guns.

A few words relative to the construction of guns of concentric cylinders of mild steel. I brought this matter up at the Annual Convention of the American Society of Civil Engineers, held at Deer Park, Md., in June, 1885. Should casting prove a failure, then we have in this method of building up guns a purely American idea—one that, so far as limited experience and careful study will permit, holds out strong hopes of success. Mr. F. J. Seymour, Superintendent of Brown Bros. Works, at Waterbury, Conn., was in special charge of the production of the cartridge metal to be supplied us at Frankford Arsenal, and, being entrusted with the inspection of the product, I became well acquainted with him. He conceived the idea that large disks of mild steel might be treated very much like copper, and he proposed to draw or fold tubes, initially hot, finally cold, thus producing true cylinders free from defect, for externally and internally they could be carefully scrutinized, and of greatly increased strength—a result of the condensing effect of the cold flow. I was struck with the simplicity of the idea, and saw its applicability for lining our stock of cast-iron guns. A subsequent visit to Cleveland convinced me that the plan was practicable. These superimposed cylinders, forced or brazed upon each other, yield all the advantages of the favored circumferential wire winding, affording the greatest tangential resistance, and, in addition, offering a maximum longitudinal resistance, the tensile strength of the material, the goal for which the advocates of wire-wound guns are striving. I enclose herewith rude tracings of a 5-inch and 12-inch built-up rifle, and of the proposed method of converting a cast-iron gun—sketches presented at the meeting mentioned. With two original, apparently feasible plans of constructing guns at command, ought we not at least to make the attempt to deviate from still unended, though well-trodden, paths? During the past few years Mr. Dorsey has made a specialty of the study of steel for structural purposes, and on various occasions, at meetings of societies of which we are both members, I have been much indebted to him for valuable information, not elsewhere readily obtainable, upon this most interesting and important subject.

THEODORE COOPER, *Consulting Engineer*, 35 *Broadway, New York.*

Each of the various grades of steel has a special field, for which it is the best, whether it be that which approximates the diamond in hardness, or that which almost equals lead in its pliability. To say

soft or mild steel is the most suitable for guns or any other purpose, because it is the best for boilers, is fully as erroneous as saying hard steel is suitable for boilers because it is the most suitable for tools and other purposes.

The suitability of a particular grade of steel for any purpose, or the best steel to use for a special object, must be finally determined by experiment and actual use.

By these means we are able to state approximately that certain grades are, under our present experience, the best for boilers, rails, machinery and the various classes of tools. We are, however, even in these special fields, constantly gaining in knowledge by the study of defects and causes of failure.

It is not possible to establish by *à priori* reasoning the best grade of steel for some new and untried purpose; but we can, by a careful study of the properties of the various grades of steel, processes of manufacture through which the material must pass before it reaches its final condition, and the duties to be performed by the material in its new purpose, determine the direction in which we may hope for the most suitable material.

The properties most affecting the suitability of the material are the tensile strength, ductility, elasticity, hardness, purity and homogeneity.

The last two, purity and homogeneity, may be assumed as essential for all purposes where the best results are desired. The other properties, in their infinite varieties, are the ones which, other things being equal, determine the appropriateness of the material.

If these properties increased together, the solution would be very simple; but such is not the case: the tensile strength and hardness increase as the ductility decreases. So, where we desire all of these qualities, we must balance their relative merits or desirability, and select the one appearing to give the best result for our particular purpose.

We must, at the same time, consider well the service to be done, and also the effects that the processes of manufacture may have upon the apparently desirable grade of metal. For boilers we must not only select a grade of steel that will properly perform the duty of resisting the internal pressures, but one which will bear the severe manipulations of bending, flanging, punching, riveting, caulking, etc., with the least injury, and also can be subjected to the trying conditions of heat and cold without serious effects.

For bridges, where it is very tempting to strive for the strongest class of steel, we are in like manner compelled to seek the highest grade which can be put through the manipulations of the several processes with the least permanent injury, and also which *after completion* will be the best to resist the shocks and vibrations of the rapidly moving loads.

For castings or heavy forging we must in like manner not only bear in mind the final purpose for which it is to be used, but the liability of the particular steel to be injured by the forming and cooling of such masses.

Much misunderstanding and false conclusions have arisen from the misuse of the terms tensile strength, ductility and elasticity.

By *tensile strength* we mean the ultimate or breaking strength of a prismatic bar of the metal under the steadily increasing strain of a testing machine continuously applied until rupture occurs.

The form and size of the specimen have a very great influence upon the final result. The difference of the strength of specimens and the strength of large masses from which the specimens may be cut is also very great. The suddenness of the application of the load is also an important factor. A piece loaded repeatedly far below the amount which one continuous test would give as the breaking strain, will finally rupture. The number of loadings governs, therefore, the maximum strain to which the piece can be repeatedly strained.

By *ductility* we mean the permanent deformation or elongation that the piece undergoes, in one continuous testing, up to rupture. It is usually measured in percentage upon a length originally eight inches long.

3. By *elasticity* we mean the amount of deformation or elongation that the piece can undergo without injury or permanent alteration of form or dimension; returning to its original shape and size upon relaxing the deforming forces.

By *hardness*, the relative resistance to wear or abrasion.

The extent to which any piece can be strained without producing any permanent alteration of form is called the *limit of elasticity*. This is usually determined in the testing machine by a series of continuous applications.

That in practice, where our applications of the loads are not statical, as in the testing machine, the limit of elasticity may be different from the usually accepted elastic limit, is very probable. As before stated, neglect of the effects of repeated loads and of impulsive loads instead of statical ones has led to much error.

The knowledge we possess to-day of the strength of materials has been obtained primarily from the practical use of such materials in their various forms, rather than from the study of the numerous tests made upon such materials. Failures in practice and tentative changes of form and proportions have led us to the use of certain shapes and allowed strains. The testing machine has followed these results and analyzed the principles underlying these forms and allowed strains.

As we study these, we must see that it is not a question solely of tensile strength, but of the amount of work a particular form or material can do under the special forces acting upon it.

To resist impulsive forces—and we may safely assume that in practice we seldom have simple statical forces to resist—it is necessary to meet them by *work* done. The strongest material from the tensile-strength point of view may be the weakest for our purpose. A hempen cable would take with ease the surging of a vessel, where a cast iron chain or bar of many times its tensile strength would snap in pieces.

The work that a hempen cable can perform is of two kinds. First, if it is such that the cable remains uninjured after the duty is performed, we can call it the *elastic work*; for the cable has not been stretched beyond its elastic limit, and has returned to its original length and condition. Second, the cable may be unbroken, but less able to perform continued duty of the same kind. It has then performed work by permanently stretching, and will ultimately break upon repetitions of the same duty.

Now, every material has, in like manner, an ability to resist impulsive forces by its elastic work and by its work of stretch or deformation.

Structures that perform their duty by the elastic work only so that they are as fully prepared to resist a repetition of their loading as in the beginning, can be classed relatively as permanent structures.

Structures, however, which are less able to resist repetitions of the load can be classed as temporary structures. Such structures may be worked up to higher strains as the number of possible repetitions of their duty is less. In all such structures relative economy, convenience of size, etc., govern the selection of the proper material and proportions.

In selecting the proper material for any purpose, therefore, we must [illegible]ly consider, not its tensile strength only, but its ability to do [illegible] kinds of work and to resist for a desired number of times a [illegible]ty.

Having thus briefly explained the general principles governing the selection of the proper material, let us consider them briefly as applied to the gun question.

Now, a gun under severe service charges can be considered as a temporary structure. Its life, relative to its cost and weight, is its measure of value.

Eliminating for the present all considerations of processes of manufacture, and the strains induced by the same, we can assume that the most destructive actions upon a rifled gun are the overstrains due to the suddenly expansive gases, erosion and abrasion. To resist the erosion and abrasion, it would seem, to one who has given no special study to this subject of guns, as assumable that it is desirable to have the hardest material consistent with its ability to best resist the impulsive forces of the explosive.

As before explained, the impulsive forces must be met by an equal work done by the material, consisting, first, of the work of elasticity, and secondly, of the work of permanent deformation.

Bearing in mind that the capacity for elastic work is approximately the same for each application of the forces, while the work of deformation, as usually measured by the tensile strength and elongation, is a definite quantity from which each discharge is withdrawing a portion, it becomes clear that we should aim toward the material having the greatest capacity for elastic work. The elastic work may be used an indefinite number of times, but the work of deformation but once.

As we pass toward the higher steels, the capacity for elastic work increases almost as the square of the tensile strength; or, in other words, a steel with double the tensile strength of another grade has approximately four times the elastic work of the lower steel. For any assumed duty, the greater the work done by the elasticity the less work remains to be overcome by the work of deformation.

Practically, the amount of allowed deformation, as measured upon the bore of a gun, must be very small. We therefore cannot depend much upon the work of deformation to resist the impulsive strains of the gases, but mostly, if not entirely, upon the elastic capabilities. We should, however, have a material possessing a certain reserve of deformation power or work, to provide against disastrous explosion of the gun in actual service.

It therefore seems to me desirable to obtain the highest steel which can give the desired reserve of deformation, and which can be put into the form of a finished gun without injurious strains from the

processes of manufacture, and which can stand the heating and cooling of actual service without injury.

That such a gun can be made in preference from what is called hard steel, instead of soft steel, I fully believe.

I do not wish to convey the idea that the steel called for under the Naval Specifications is therefore the best, but only that a high steel in preference should be sought after.

In one thing I can agree with the author: The only true and possible method of determining the best steel must ultimately be by actual construction and service of the gun.

With full faith in the ability of our manufacturers to develop new and better methods of manufacturing, and in connection therewith, to assist in the selection of the best grade of material, I claim that an effort should be made to combine, without unnecessary trammels, the technical knowledge of the manufacturer and the ordnance officer.

The past history of the Fort Pitt Foundry, in connection with the ability of a Rodman under like circumstances, can be repeated for steel guns.

If a prospective order for a number of guns could be assured our manufacturers upon the success of sample guns, an incentive would be given which would, I fully believe, produce excellent results. Instead of following simply in the same paths as European governments, we should at least give an opportunity for the development of that hard common sense and practical ingenuity, free from the trammels of blind precedence, for which our manufacturers and engineers have become renowned in all the branches of civil construction.

Allow full latitude to manufacturers in the selection of their material and in their processes of manufacture, holding them solely to the desired requirements in the finished gun. The practical knowledge of Whitworth, Armstrong, Krupp and others, has been a strong feature in the advancement made in European countries in the gun question. Why should not American metal-workers have also a fair field in the same direction?

Personally, I do not believe we have even yet exhausted the possibilities of our cast iron; and I am not yet of the opinion that, with a good opportunity to develop the proper method of casting steel guns, an equally excellent result cannot be made with this metal that formerly we were able to do with our cast iron.

Asking your indulgence for these incomplete and somewhat crude remarks, I tender you my thanks for the invitation to discuss this paper.

## NEWPORT BRANCH.

DECEMBER 29, 1886.

COMMANDER C. F. GOODRICH, U. S. N., Vice-President of the Naval Institute, in the Chair.

The paper of Mr. Edward Bates Dorsey, C. E., was read by the Corresponding Secretary of the Branch, and the following discussion took place:

Professor RAPHAEL PUMPELLY.—*Mr. Chairman and Gentlemen:* I regret that it will be impossible for me to be present at the reading of Mr. Dorsey's very timely warning. While not familiar with the requirements of heavy ordnance in regard to qualities in steel, nor with the intentions of the Government in the matter, I fully agree with Mr. Dorsey on the general question of the decrease of the trustworthiness as the thickness of hard-steel masses increases. The more rapid increase of volume near the surface than in the interior produces, as is well known, a great textural strain.

It may be an open question whether in a thick body, even of an ideally perfect quality of steel, the oil-bath can restore the desired equilibrium; but, in view of irregularities that practically exist in the various steels, there would seem to exist a real danger that in this unequal strain produced in hardening, there may be produced in thick articles minute ruptures, or permanent disturbances, equally undesirable with those formed in cold-punching or shearing, and which, of course, would not be remedied by the oil-bath. This is one of the points that can be settled only by thorough experiments on the various steels.

Colonel GEO. H. ELLIOT, *Engineer Corps U. S. A.*—I much regret that I cannot be present at the meeting of the Institute this evening, to listen to the discussion of Mr. Dorsey's interesting and valuable paper, but I send you herewith some extracts from a recently published paper by Mr. Benjamin Baker, of the Forth Bridge R. R., entitled * "Some Notes on the Working Stress of Iron and Steel," which may be interesting to the Institute.

Although Mr. Baker's experiments were not made in connection

* Engineering News and American Contractors Journal, 16, 397-399; Dec. 18, 1886.

with the construction of heavy guns, they appear to tend to confirm Mr. Dorsey's conclusions.

"Wöhler's experiments on the so-termed 'fatigue' of metals are well known. The writer, wishing to satisfy himself as to the behavior of modern structural steel under different stresses, has, during the past few years, carried out experiments in some respects similar to, and in others differing from, those of Wöhler, and has also made analogous tests of hard steel and of iron. The experiments may be roughly classified under four heads: (1) Rotating spindles, with a weight at the free end, causing alternate tension and compression on the fibres as the spindle revolves; (2) Flat bars bent in some cases one way only, and in other cases both ways; (3) Specimens so designed as to give alternate direct tension and compression on small pieces of metal; and (4) Full-sized riveted girders.

SERIES NO. 1.

| Number of Revolutions. | | Stress per Square Inch. | Factor *a*. | Factor *b*. |
|---|---|---|---|---|
| | | *Soft Steel.* | | |
| 1 | 40,510 | 36,000 | 1.75 | 2.45 |
| 2 | 60,200 | 36,000 | 1.75 | 2.45 |
| 3 | 68,400 | 34,000 | 1.84 | 2.56 |
| 4 | 92,070 | 34,000 | 1.84 | 2.56 |
| 5 | 107,415 | 34,000 | 1.84 | 2.56 |
| 6 | 128,610 | 34,000 | 1.84 | 2.56 |
| 7 | 155,295 | 34,000 | 1.84 | 2.56 |
| 8 | 14,876,432 | 26,000 | 2.42 | 3.4 |
| | | *Hard Steel.* | | |
| 9 | 5,760 | 67,000 | 1.88 | 2.82 |
| 10 | 7,560 | 65,000 | 1.93 | 2.90 |
| 11 | 14,600 | 53,500 | 2.36 | 3.45 |
| 12 | 16,300 | 53,500 | 2.36 | 3.45 |
| 13 | 26,100 | 46,500 | 2.72 | 4.10 |
| 14 | 32,405 | 51,000 | 2.40 | 3.60 |
| 15 | 157,815 | 40,500 | 3.03 | 4.55 |
| 16 | 472,500 | 34,000 | 3.70 | 5.55 |
| | | *Best Bar Iron.* | | |
| 17 | 108,160 | 34,000 | 1.70 | 2.38 |
| 18 | 110,000 | 35,000 | 1.66 | 2.32 |
| 19 | 141,750 | 34,000 | 1.70 | 2.38 |
| 20 | 389,050 | 32,000 | 1.90 | 2.65 |
| 21 | 408,000 | 30,200 | 2.00 | 2.80 |
| 22 | 421,470 | 32,000 | 1.90 | 2.67 |
| 23 | 480,810 | 31,000 | 1.95 | 2.75 |

"The above series includes a representative number of the writer's experiments with rotating spindles. As a rule, the spindles were one inch diameter and projected about ten inches from the end of the revolving shaft in which they were fixed. A speed between fifty and sixty revolutions per minute was maintained day and night.

"The 'soft steel' was fine rivet steel having a tensile strength of from 60,000 to 64,000 pounds per square inch, and an elongation of 28 per cent. in 8 inches. The 'hard steel' was a high-class 'drift' steel having a tensile strength double the above, and an elongation of one-half the extent. The 'iron' was the best rivet iron, having a tensile strength of from 58,000 to 61,000 pounds, and an elongation of 20 per cent.

"Factor *a* is the ultimate tensile strength per square inch of the specimen divided by the calculated stress upon the outside fibres, due to the load on the end of the projecting bar. Factor *b* is the ratio of the static load required to bend the bar a moderate amount beyond the elastic limit, to the load actually imposed upon the revolving bar. These definitions will be made more clear in further references to the table.

SERIES NO. 2.

*Soft Steel.*

| | No. of Bends. | Stress per Square Inch. | Factor *a*. |
|---|---|---|---|
| 24 | 12,240 | 44,000 | 1.59 |
| 25 | 12,325 | 44,000 | 1.59 |
| 26 | 12,410 | 44,000 | 1.59 |
| 27 | 18,100 | 42,000 | 1.67 |
| 28 | 18,140 | 42,000 | 1.67 |
| 29 | 72,420 | 36,000 | 1.94 |
| 30 | 147,390 | 34,500 | 2.03 |
| 31 | 262,680 | 34,000 | 2.05 |
| 32 | 1,183,200 | 27,500 | 2.55 |
| 33 | 3,145,020 | 34,500 | 2.03 |

*Best Bar Iron.*

| | | | |
|---|---|---|---|
| 34 | 184,875 | 34,000 | 1.68 |
| 35 | 250,513 | 34,000 | 1.68 |
| 36 | 3,145,020 | 34,000 | 1.68 |

"The above series is a selection from the writer's experiments with flat bars bent laterally. Generally the bars were one inch wide by one-half inch thick, and thirty-two inches long between the bearings.

"The steel specimens were cut from the tension member plates of the Forth bridge, and had a tensile strength of about 70,000 pounds per square inch, and an elongation of twenty per cent. in eight inches. The iron specimens were rolled bars.

"A careful consideration of the results of the preceding experiments will, the writer thinks, illustrate many points of interest to practical engineers. Experience has shown that screw shafts and axles generally, made of the finest quality of high-tension steel, are not practically as strong as when made of soft steel, having theoretically, perhaps, little more than half the strength of the former.

"Referring to Series No. 1, we find, comparing Experiments Nos. 8 and 14, that under working stresses in each case equal to about forty per cent. of the ultimate strength, the hard steel failed with only 32,445 revolutions, while the soft steel stood 14,876,432. Again, comparing Experiments Nos. 16 and 23, it will be seen that with practically the same number of revolutions the hard steel, though more than double the tensile strength of the iron, broke under a working stress only ten per cent. greater. It is impossible, in the face of results such as these, to contend that the ordinary laboratory tests of a metal give any adequate measure of its value as a material of construction.

"Iron of high quality holds its own, as compared with mild steel, in these experiments, and this is consistent with the general experience as to the driving axles of locomotives, which are subject to repeated bendings of considerable severity. Certain of the soft-steel specimens would have given higher results had they not been turned down, as fracture occasionally appeared to have been accelerated by the slight tool-marking. On the other hand, No. 8 stood exceptionally well, although it was a turned-down specimen. All of the hard-steel bars were put in with the skin on.

"An illusion entertained by some engineers that alternating stresses are destructive only if the stress exceeds the elastic limit, is effectually disposed of by these experiments, because none of the stresses in question exceeded the said limit, and some of them were very far below it.

"Thus, in Experiment 16, the working stress was but one-half of the stress at the elastic limit under direct tension, and only one-third of the stress at the elastic limit of the material when under transverse stress, which was really the condition of the specimen in the experiment. Factor *b*, in the case of Experiment 16, has a value of 5.55,

which means that less than one-fifth of the static weight required to bend a hard-steel pin a small amount, will suffice to fracture the pin if the stress be alternating, as in the case of the pins of connecting-rods, for example. If we take what is usually termed the breaking load, or, say in a ductile material like steel, the stress which would deflect the bar as a beam an amount equal to half the span, then the load which ultimately broke the bar in Experiment 16 was only one-seventh of the original static breaking load—a sufficiently remarkable result.

"Other points of interest may be referred to in connection with Series 2. In general the bars were tested in pairs, so that when one bar broke its companion could be otherwise tested and examined. For example, the companion to No. 28, after being subjected to 18,140 bendings, was tested for tension, and failed with 48,000 pounds per square inch, and 2.6 per cent. elongation, the original strength of the steel being 70,000 pounds and 20 per cent. elongation.

"Again, the companion of No. 32 was, on close examination, found to have a flaw like those found in crank shafts. Nos. 33 and 36 were companion bars, bent one way only, so that the stresses were not alternating; hence the largely increased endurance.

"They were both taken out before actual fracture, but with deep-set flaws, clearly illustrating that the cause of failure under repeated stresses is very frequently not so much a gradual deterioration or crystallization of the metal, as the establishment of small but growing flaws. This, of course, is well known to locomotive and marine engineers; and on some railways it is the custom to run crank axles until the incipient flaw is detectable, and then to hoop the web of the cranks; whilst marine surveyors do not condemn a shaft necessarily on the first appearance of a flaw, but license it to be run for a further definite period.

"Another noteworthy fact illustrated by these experiments was, that a structure or piece of mechanism may be subjected to a repeated stress equal to ninety per cent. of that which would break it, and yet specimens cut from the metal may exhibit no signs whatsoever of deterioration. The broken half of nearly every specimen in Series No. 2 was tested by the writer with that result.

"Thus, as the stress was applied at the centre of the bars, it followed that at a point ninety per cent. of the half span from the bearings the stress would be ninety per cent. of that which broke the bar.

"Although the bars broke short off at the centre at the point referred

to, they could invariably be bent double without fracture. Having reference to this fact, and to the fact that the tensile strength was also a little affected, it is clearly hopeless to expect to learn much from testing specimens of metal from structures or machines which have been long in use. Unless the experimenter happens to hit off the right moment immediately preceding the commencement of failure, he need not expect to learn much from the behavior of the metal in the testing machine. Professor Kennedy, in an interesting and instructive lecture recently delivered before the Royal Engineers at Chatham, has given the results of tests of forty-seven pieces of iron and steel which had either been in constant use for many years until they were so much worn as to require renewal, or which had been broken in actual use; but in no case did he find anything distinctly pointing to a weakening effect due to actual fatigue.

"This is exactly the result which the writer's experiments would have led him to anticipate; but it by no means follows that the very piece of metal tested by Professor Kennedy, and found uninjured, would not have broken a few days after in actual working. A man of seventy years of age may be as sound as he was at twenty, but the fifty years have told on him nevertheless, and the breakdown is certainly near and may be sudden. Having referred to Professor Kennedy's lecture, it is necessary, perhaps, for the writer to say that he does not agree in some conclusions set forth therein. Thus, Professor Kennedy expresses his belief that the failure of coupling-rods occurs as much by the gradual disintegration of the dirt between the laminations, and the oxidation of the iron, as by vibration and repetition of load; and that a homogeneous material like steel remains comparatively uninjured by repetition. This, of course, is negatived by the results of the experiments cited in the present paper. Professor Kennedy further says: 'If a load exceeding the limit of elasticity be applied a considerable number of times, the bar will be actually broken; but, at the same time, we know that if any load exceeding the limit of elasticity be but once applied, the structure to which the bar belongs is distorted and rendered useless.' This, the writer thinks, is a dangerous fallacy, tending to delay the application of truly scientific principles to the design of structures and mechanism.

"In concluding this necessarily very hurried and imperfect paper, the writer would like to bear testimony to the admirable behavior of a very good friend of his—*mild steel.* During the past three years

he has had to deal with about 24,000 tons of that material, and to submit it in many cases to very harsh treatment. He has had more cases of so-termed 'mysterious fractures' with the few tons of wrought iron used for certain temporary purposes, than with the whole 24,000 tons of steel. The rest of his experience may be of interest to brother members of this society who now are, or will doubtless be, large users of mild steel; and the testimony is perhaps of the greater value as the work at the Forth is pressed on day and night, and no precautions are taken which would not equally be necessary were the material of the highest class of Lowmoor iron, costing double or treble the price of the steel."

Colonel E. H. HEWINS.—Some years ago I was entrusted with the building and charge of operating a testing machine, and perhaps my experience with it may be of some value to you. The machine was one of the largest, and undoubtedly the most accurate large testing machine in this country until the construction of the Government machine now at the Watertown Arsenal. We could test up to one hundred and fifty tons, dead pull, and with that amount of strain on we could measure accurately increments of less than one-quarter of a ton. My experience may serve to assist you in discovering the source of the discrepancies among your data. At the outset, when using this machine, we met with the same apparently conflicting results, and on consideration I concluded that they were due to our inability to observe and record accurately. Soon after, we constructed an automatic registering apparatus, and the conflicting results largely disappeared. These experiments were made on iron. Hence I cannot say whether or not as concordant results would have been obtained with steel. Comparisons of the results of the tests of different specimens cannot be so intelligently made by means of tables of figures as they can by the use of diagrams. By the use of the latter the comparisons may be instituted with readiness and accuracy. These diagrams bear the same relation to the action of the test specimens that steam-indicator diagrams do to the action of the steam within the cylinder, and those we made were similar to those produced by Prof. Thurston.

These tests were made on long bars—longer, I suppose, than would be necessary for any such purpose as the steel under discussion would be used for. Sometimes bars thirty feet in length, intended for bridge-building, were tested. I have broken such bars with 140 to 150 tons

strain upon them. In the diagrams taken, the vertical direction represented the strain upon the bar, and the horizontal the elongation of the bar. (The method used was illustrated on the blackboard.) The portion of the resultant curve just before reaching the elastic limit seems to be the most important for consideration, since strains within this limit are those to be dealt with in practice. When we go beyond the elastic limit the curve takes a sudden change of direction of nearly 90°. Sometimes the diagram will take a form showing a continually increasing strain until the bar breaks short off with the highest strain reached. Sometimes the maximum is not the breaking strain, but as the bar extends the strain reduces more or less. I cannot express an opinion as to which form of diagram would indicate the best quality of metal for gun purposes or for the different parts of guns. If you have diagrams like this and wish to compare the specimens, you can do so with greater certainty than is possible in any other way. For bridge-work it is one of the best ways of determining whether or not the bars are uniform. If you are going to have several bars parallel to each other, or you are going to build up a barrel of hoops, each should with certainty receive its strain at some predetermined time, for if they have different moduli of elasticity and receive their strains at the same time, one bar or hoop will expand more under the same strain than another, and they will ultimately be broken in detail. I do not mean that the elasticity need be the same in the different hoops, but by this means we could select hoops to bear the strain which is to be put on them. This question of the modulus of elasticity, as well as that of the elastic limit, is of the first importance. The elastic limit might be the same in two bars, yet one bar might extend twice as far as the other under the same strain. By the diagrams certain results may be recorded which no human eye could have observed, and from them we can obtain the modulus of elasticity, the limit of elasticity, the maximum strain to which the bar had been subjected, the breaking strain, and the elongation. The specific gravity of the metal, both before and after testing, should be ascertained, for much can be predicted concerning the adaptability of the metal if this be known. In testing metals the specimens should be as nearly alike in dimensions as possible for convenience of comparisons. If the sectional area were twice as large in one specimen as in another, the diagram would be twice as high.

In my opinion the question of molecular condition is one of the first importance. Unless you know that, you cannot tell what internal

strains there may be in it, but undoubtedly the oil-tempering and annealing largely eliminate such internal strains. You cannot forge large masses under any hammer that is known without producing internal strains, and therefore it seems to me very important to employ hydraulic presses for forging. In this way only can the mass be forged to a uniform density, and this would leave less work for the annealing to accomplish, which process would thereby be made of more value in its final results.

Professor CHARLES E. MUNROE.—In discussing this paper of Mr. Dorsey's, we observe that he contents himself with assertions; but it cannot for this reason be presumed that he is not fortified with data which he believes support his position; and, as a consequence, in order to meet him and disprove his statements, it will be necessary to present experimental data, or results of experience, which support the Ordnance Bureau and outweigh in value those he may quote. For, unless this can be done, it would be very unwise to go to large expense in the construction of ordnance, when the factors which form the important elements which determine success are yet disputed, and we had better confine ourselves within assured limits.

As for myself, I must confess that I am unprepared to furnish such data, nor have I been able to find them; but as some of our members have, in the performance of their duties, been called upon to study this problem, we shall have, I trust, before this discussion is completed, a full presentation of all the facts and data which have led to the adoption of the requirements set forth in the Bureau's specifications. If this be done, Mr. Dorsey will certainly have rendered the members of the Institute, and all of the many citizens of our country who are interested in the modern development of ordnance, a most valuable service. In fact, such examples as I have discovered in the limited time at my command seem rather to support Mr. Dorsey's position. Thus, for guns, we find in the reports of the Chief of Ordnance a complete account of the construction and proving of the 8-inch B. L. chambered rifles. These contained a wrought-iron tube. The breech receiver, block and band were made of English steel received from Firth & Co., Sheffield. The receiver and band were oil-tempered. The tests of these materials have been compiled in the following table, and show that the steel falls in the class defined as "hard":

* *Firth's Steel from Breech Block and Jacket of 8-Inch B. L. C. R.*

| Specimens. | Tensile Strength | Elastic Limit. | Elongation. | Part fr'm which Taken. |
|---|---|---|---|---|
| | Pounds | Pounds | Per ct. | |
| B. B. 7 inches long, 0.651 inch diameter......... | 66,000 | 21,000 | 21.43 | |
| B. B. 7 inches long, 0.652 inch diameter......... | 70,000 | 34,000 | 14.75 | |
| B. B. 7 inches long, 0.652 inch diameter ........ | 82,440 | 23,000 | 20.31 | |
| J. (O. T.) 3 inches long, 0.653 inch diameter... | 92,000 | 45,000 | 16.00 | Radially |
| J. 3 inches long, 0.651 inch diameter............ | 104,480 | 45,000 | 11.13 | |
| J. (O. T.) 3 inches long, 0.653 inch diameter... | 102,000 | 61,000 | 8.33 | Interior. |
| J. (O. T.) 3 inches long, 0.653 inch diameter... | 82,000 | 42,000 | 25.83 | Interior. |
| B. B. 10 inches long, 0.0652 inch diameter...... | 62,000 | 20,000 | 21.75 | |

B. B.=breech block; J.=jacket; O. T.=oil-tempered.

*Ulster Iron for Tube 8-Inch B. L. C. R.*

| | | | | |
|---|---|---|---|---|
| Mean of four results.................................. | 49,250 | 26,750 | 30 | |

† Five of these guns were finished during the year ending June, 1881, and proved at Sandy Hook. One of them broke at the third round. This being claimed to have been due to the angular corners of the breech slot, these corners were rounded, the gun repaired and proved again. After 122 rounds the gun burst violently into numerous fragments, the tube being the least fractured. The average pressure of the last seven (and heaviest) rounds was 51,000 pounds, and the velocity 1710 feet. These pressures were not regarded as excessive, and were such as were quite likely to have occurred in the service use of the gun.

In discussing this failure, the Board held that the successful results previously obtained in the tests of the M. L. converted guns, and of an 8-inch B. L. R., with a Krupp fermeture (tried to 500 rounds), had justified the Bureau in the procurement of others of the same calibres, and that the result of this trial showed the difficulty of obtaining suitable steel for their construction.

It would be at least interesting if we could secure for comparison here the results of tests of the metal of this 8-inch gun whose successful action led to the order for the guns which failed.

In regard to the Krupp guns, which are regarded as almost standard, we find, in addition to the statement quoted by Mr. Dorsey, that Colonel Hennebert claims the material to be far from irreproachable; for, during the war with Bohemia, several Krupp field-pieces burst. After the war, in order to allay public agitation, trials *à outrance* were made, and these cost several young officers their lives. In 1868, General de Bœuf declared that several guns, firing ordinary charges,

* Report Chief of Ordnance U. S. A., pp. 395–408; 1881.
† *Ibid.* pp. 489–499; 1882.

had burst; nor can it be said that the Russian steel guns of to-day are safe. In fact, between 1867 and 1870 numerous accidents occurred in Russia, England, Germany and Italy, on land and on board ship. Colonel Hennebert says that during the Franco-German war 200 Krupp guns burst. At Versailles it was thought that if the French had held out a week longer, the German siege batteries would have been reduced to silence. It is equally certain that during the campaign on the Loire Prince Frederick Charles had twenty-four of his guns disabled by their own fire.

In regard to the question of unreliability in steel, we have, among others, the remarkable instance quoted from the *Engineer* in *Proc. Nav. Inst.* **12**, 241; 1886, where several boilers, constructed of steel which had passed all the tests required by the Board of Trade and Lloyd's, and which withstood all the processes of manipulation in the workshop, welding included, suddenly, after two and a half years' satisfactory use at sea, exhibited signs of a complete change in the character of the steel, which had become extremely brittle, and developed extensive fractures under very slight blows.

Again, in the *Engineer* for November 12 we find a steel plate, which possessed a tensile strength of 28.25 tons, an elongation of 21.25 per cent., and a composition of C. 149, S. 0.11, S. .042, P. .034, Mn. .574 per cent., developed a crack while being hammered in the boiler-shop. This was evidently mild steel, and it had passed inspection for the use to which it was to be put. The only peculiarity in working it was in heating it to a dull red heat for rolling; yet this seemed to have caused the metal to become brittle.

Mr. Dorsey has limited his criticism to the materials for hoops, but if his position be verified, his conclusions will apply equally to the tubes. Recent specifications require that these shall have a tensile strength of 80,000–72,000 pounds, an elastic limit of 35,000–31,500, and an elongation of 18–16.2 per cent. In considering the use of this material, we ought to bear in mind the results of the recent experiments of Sir Frederick Abel and Colonel Maitland.* Although not yet completed, they seem to show that the erosion of the tube by the action of the powder gases is markedly increased with the increase in size of the gun, and with increase in the hardness of the steel. This factor is so important a one in determining the life of a gun that it cannot be neglected.

In the course of these desultory remarks, permit me to say a word

**Engineer*, **62**, 292; Oct. 8, 1886.

about the methods of testing. As now conducted, it is the custom to take small samples—of two inches cross-section or thereabouts, and various lengths—from the mass, upon which to make the tests. Now, any chemist who has ever sampled a solid, heterogeneous mass for analysis, knows how very difficult it is to get two samples that agree exactly, and that, as a consequence, we must admit a large tolerance in our results. The same must be true in sampling a mass of steel for physical tests. On the other hand, I question if it is really known what numerical relation the tensile strength and other properties of a mass of steel bear to any unit section of the mass as tested by itself. We do know that as the cross-section diminishes, the tests for tensile strength give higher results. As for the tensile strength, so in the shocking test a small section of the specimen is employed. This test is conducted by allowing a hammer of known weight to fall through a measured distance upon the sample bar, this bar being supported near its two ends upon knife-edges, or over a hole in an anvil. This seems to me the most important test to which a metal for use in guns should be put, for the property of resisting a shock to a high degree is the most valuable property which gun metal can possess. In considering this subject, it has occurred to me that we possess in gun-cotton a substance which will enable us to test the resistance of a metal to shock, and that the test may be applied, not to a small sample, but to the original ingot from which the portion of the gun is to be formed. I have been led to this conclusion from observing the effect of gun-cotton upon the metals used in my experiments. Thus, I have found that when a ten-ounce disk of gun-cotton is placed unconfined upon plates of Swedish iron one-half inch thick and detonated, the iron is indented to a depth of about one-eighth of an inch, but the plates show little or no signs of fissuring. When a similar disk of gun-cotton is placed on a disk of hard steel two and a half inches thick, the steel disk is shattered to fragments. Should this suggestion be found worthy of consideration, we could easily determine by experiment the amount of gun-cotton required for the test, and the distance at which it is to be placed from the object. It may be urged that this test is in excess of any strain to which a gun charged with powder may be exposed; but the answer to this is that it is always good practice to expose an element in a structure to the test of a greater load than it will be called upon to carry when in use.

In closing, I would remark that if Mr. Dorsey's conclusions regarding the subdivision of the hoops be pushed to their ultimate consequences, we are led to the use of wire for the hoops.

Commander GOODRICH.—To profitably discuss a subject, it is necessary at the outset to adopt a system of definitions, so that the disputants may understand each other. The author's definitions are inadequate. He limits mild steel to that having a certain tensile strength coupled with a bending test. He mentions also that there should be a very low, but unstated, percentage of carbon.

It is hard to argue when the elements of the question are so obscure. Briefly, he accuses us of using treacherous metal in our new guns. Is this true?

Without dwelling on the significant fact that we have in this paper mere conjecture and absolutely no proofs, let me ask how the author would class steel having twenty per cent. elongation and forty per cent. stricture in a two-inch test specimen? Surely not as hard. Yet these are the average characteristics of our eight-inch gun-hoop steel. If, having secured a sufficiently ductile metal, we get, in addition, a high elastic limit, our gun must be stronger than if made of weaker material.

For the tube and jacket, the present system of gun construction exacts a more yielding metal, that all the layers of the gun wall may reach the elastic limit at the same time. Practically, the characteristics of the hoop dominate those of the tube and jacket. Given the strongest hoop compatible with absolute security, the tube and jacket steel must be graded down in accordance, so as to obtain the maximum value of the compound structure. Now, this gradation is secured by slightly varying the percentage of carbon coupled with oil-tempering and subsequent annealing. The latter process, which relieves internal strains and secures the necessary ductility, is not so much as alluded to by the writer.

Are we to understand that mild steel is not acted on by the process of oil-tempering? The behavior of the gun shields for the new cruisers, all of which are so treated, negatives such an inference, as does the case of the Cambria locomotive tire, which, after tempering and annealing, had 110,700 pounds tensile strength, 57,180 pounds elastic limit, 17½ per cent. elongation in 2½ inches and 47.2 per cent. reduction in area.* Would Mr. Dorsey hesitate to use such a tire on a locomotive?

I have here the record of the E-hoop of 8-inch B. L. R. No. 2. Its tensile strength is 85,816 pounds, its elastic limit is 34,887 pounds, its elongation is 29.55 per cent., and its reduction of area is 47.29 per cent. That is ductile enough, surely. It is indeed mild

* Report of the Chief of Ordnance, 1885.

steel. We temper and anneal it, raising its tensile strength to 104,659 pounds and its elastic limit to 54,748 pounds without unduly sacrificing the other characteristics. And yet we are to be condemned for increasing the elastic limit by over a half!

I am indebted to Mr. Davenport, the Superintendent of the Midvale Steel Works, for the following table illustrating the effect of oil-tempering and annealing on the mild steel used in our guns, adding that the mechanics at the Washington Navy Yard are unanimous as to its uniform quality.

*Tubes.*

| | Midvale Tests. Before Treatment. | | | | Washington Tests. After Treatment. | | |
|---|---|---|---|---|---|---|---|
| | Tensile Strength. | Extension. | Contraction. | Position of Test Piece. | Tensile Strength. | Extension. | Contraction. |
| No. 12. | | | | | | | |
| H. 5798 | 82,709 | 16.5 | 22.56 | M.T.C. | 79,387 | 23.95 | 48.37 |
| | | | | M.T.I. | 86,564 | 21.40 | 45.76 |
| | | | | B.T.C. | 82,430 | 24.80 | 43.10 |
| | | | | B.T.I. | 80,430 | 25.40 | 43.50 |
| | | | | B.L.C. | 79,640 | 25.90 | 59.30 |
| No. 21. | | | | | | | |
| H. 7142 | 74,722 | 18 | 23.61 | M.T.C. | 83,206 | 24.00 | 46.70 |
| | | | | M.T.I. | 86,920 | 22.00 | 43.70 |
| | | | | B.T.C. | 78,544 | 27.80 | 42.90 |
| | | | | B.T.I. | 78,870 | 22.70 | 49.40 |
| | | | | B.L.C. | 80,773 | 25.70 | 55.90 |
| No. 17. | | | | | | | |
| H. 7170 | 82,053 | 17 | 19.59 | M.T.C. | 87,913 | 21.90 | 46.16 |
| | | | | M.T.I. | 76,597 | 24.00 | 43.07 |
| | | | | B.T.C. | 82,807 | 25.20 | 45.83 |
| | | | | B.T.I. | 79,763 | 28.65 | 59.28 |
| | | | | B.L.C. | 76,690 | 29.55 | 53.39 |
| No. 16. | | | | | | | |
| H. 7171 | 76,129 | 16.5 | 25.30 | M.T.C. | 83,727 | 23.55 | 40.40 |
| | | | | M.T.I. | 82,301 | 26.65 | 48.70 |
| | | | | B.T.C. | 82,632 | 18.70 | 33.42 |
| | | | | B.T.I. | 87,503 | 25.00 | 49.52 |
| | | | | B.L.C. | 86,489 | 25.25 | 58.18 |
| No. 11. | | | | *Jackets.* | | | |
| H. 5423 | 89,555 | 11.5 | 16.83 | M.T.I. | 94,858 | 21.80 | 35.90 |
| | | | | M.T.C. | 98,523 | 18.40 | 31.33 |
| | | | | B.T.I. | 88,771 | 21.60 | 30.10 |
| | | | | B.T.C. | 91,641 | 19.30 | 40.20 |
| | | | | B.L.I. | 88,165 | 26.90 | 54.40 |
| | | | | B.L.C. | 87,122 | 26.80 | 55.40 |

*Jackets.*

| | Midvale Tests. Before Treatment. Tensile Strength. | Extension. | Contraction. | Position of Test Piece. | Washington Tests. After Treatment. Tensile Strength. | Extension. | Contraction. |
|---|---|---|---|---|---|---|---|
| No. 15. | | | | | | | |
| H. 6447 | 78,144 | 19 | 21.85 | M.T.C. | 90,547 | 23.01 | 45.70 |
| | | | | M.T.I. | 96,502 | 22.40 | 40.89 |
| | | | | B.T.C. | 85,138 | 19.25 | 28.48 |
| | | | | B.T.I. | 85,051 | 16.25 | 28.40 |
| | | | | B.L.C. | 86,809 | 23.00 | 48.70 |
| | | | | B.L.I. | 88,107 | 23.00 | 48.40 |
| No. 17. | | | | | | | |
| H. 7100 | 83,850 | 17 | 22.56 | M.T.C. | 102,157 | 20.65 | 40.82 |
| | | | | M.T.I. | 98,523 | 18.50 | 36.83 |
| | | | | B.T.C. | 95,744 | 19.95 | 39.65 |
| | | | | B.T.I. | 92,576 | 21.15 | 35.30 |
| | | | | B.L.C. | 94,249 | 27.65 | 51.48 |
| | | | | B.L.I. | 96,256 | 22.80 | 47.29 |
| No. 12. | | | | | | | |
| H. 5422 | 82,709 | 17 | 24.31 | M.T.I. | 92,460 | 21.45 | 37.47 |
| | | | | M.T.C. | 92,460 | 21.00 | 27.99 |
| | | | | B.T.I. | 89,528 | 22.60 | 40.53 |
| | | | | B.T.C. | 90,944 | 22.60 | 42.70 |
| | | | | B.L.I. | 87,913 | 26.50 | 53.20 |
| | | | | B.L.C. | 94,733 | 21.00 | 47.40 |
| | | | | *Hoops.* | | | |
| $A_3$ No. 16. | | | | | | | |
| H. 5681 | 79,538 | 15.5 | 22.86 | T.C. | 103,828 | 20.25 | 40.27 |
| | | | | T.I. | 107,112 | 18.50 | 40.58 |
| $A_1$ No. 11. | | | | | | | |
| H. 5688 | 81,811 | 23.5 | 37.52 | T.C. | 101,706 | 18.45 | 31.75 |
| | | | | T.I. | 105,025 | 15.20 | 27.26 |
| $A_2$ No. 19. | | | | | | | |
| H. 5692 | 97,539 | 17.00 | 26.72 | T.C. | 111,093 | 16.15 | 33.24 |
| | | | | T.I. | 115,149 | 16.40 | 37.86 |
| $A_4$ No. 15. | | | | | | | |
| H. 6387 | 100,559 | 15.00 | 29.72 | T.C. | 108,479 | 15.80 | 29.40 |
| | | | | T.I. | 106,607 | 17.10 | 34.90 |

There are three machine shops in this country where mild steel forgings of large size have been worked—at the Washington Navy Yard, at West Point, and at South Boston. I have yet to hear of one such mass cracking when completely at rest, as alleged by Mr. Dorsey. Nor are the failures of guns in England to be charged to the trustworthy product of the open hearth. Mr. Dorsey cannot quote a single failure of an English gun similar to ours in material.

Mr. Dorsey makes a good suggestion when he advises testing the value of oil-tempering on large masses. I am not disposed in this matter to throw the burden of proof on him, for guns, like some other things, must be beyond suspicion, although, strictly speaking, it is incumbent on him to establish his case.

I am particularly anxious to see this experiment tried, for the author explicitly admits that the tensile strength of mild steel may, by work, "be raised very high without impairing the quality." In other words, the tensile strength should not, alone, condemn the metal. Now, if oil-tempering a forging is not putting work either *on* it or *in* it, I should like to know what it is.

The quoted statement of the Duke of Cambridge has been made to do duty in many causes already, and I venture to predict for it a long life and a busy old age. When we remember that a gun is disabled through the breaking down of the carriage or the disarrangement of the breech mechanism, etc., as well as by absolute explosion, it becomes clear that what is needed is a detailed description of the damages sustained.

I really disapprove of hard steel as much as the author, although we may not (or may) draw the line of demarkation at the same point. Krupp used only crucible high steel, however, and what bearing the collapse of his guns, burning quick powder, has on the reputation of our Dolphin's gun, for example, with its fine record of 300 rounds, more or less, of brown powder, I am sure I do not know.

The gun steel we use is costly because it must be forged in larger masses than are common, not because its composition is expensive. The ingot, as cast, is no costlier than other ingots made from selected material. The tube cannot be eliminated, that is certain, and the jacket, or its equivalent, is necessary. Given the plant to produce them, and the hoops are really cheap. They must, however, practically bear their share of the burden equally with the tube and jacket.

I am glad that a champion has been found for good mild steel in this country, as against the cast-iron and cast-steel men; but, as has been pointed out by Professor Munroe, the author's own logic leads him to the wire gun. Now, gun wire is, by his own definition, high steel.

In conclusion, let me say that I think Mr. Dorsey has yet to show that the metal approved by all the great gunmakers of the world is untrustworthy; still, as affording us an opportunity of giving our reasons for the faith that is in us, which has produced so unusually

wide and interesting a discussion, as well as by warning us of a danger likely to be thrust upon us in the near future, he has earned our gratitude.

It is my pleasant task, before adjourning the meeting, to extend to the author the hearty thanks of the Newport Branch of the Naval Institute, as well as to express our sense of obligation to the distinguished gentlemen not members who have been kind enough to take such an active part in our discussion.

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*Submitted by* MR. E. BATES DORSEY, C. E.

In conclusion, I will give a few quotations from high authorities on steel. These show that others have my views—that open-hearth hard steel is not a safe material for constructing guns, especially large ones.

The report to the United States House of Representatives by the Randall Committee, in 1886, on "Ordnance and Warships," says: "The question of making gun steel, even in small masses, is a delicate and difficult operation." What is the necessity of this "difficult operation"? Why not make it of mild steel, which is a simple and cheap operation in any size masses?

The *Engineer* of London, a very high authority on engineering and mechanical matters, in a late number, in reference to the English steel guns bursting, says:

"The only way in which big guns can be made safe is to reject absolutely all steel which is too hard. The ordnance authorities show by the tests which they have laid down for gun steel that they do not yet fully understand what a soft steel is; or else that they have knowingly adopted a steel which is hard, for a reason which they have not stated. They say that gun steel must have a breaking stress of not less than thirty-five tons or more than forty-five tons. Now, this is flatly opposed to the practice not only of Lloyd's, but of all engineers. It is perfectly understood outside the War Office that a steel to stand tensile strains must, under no circumstances, have a greater tensile strength than thirty-two tons to the square inch, or no less than thirteen tons less than the War Office maximum, and three tons less than the War Office lowest limit. No engineer in his senses would think of making a boiler, or a bridge, or a tire, out of steel with a 45-ton limit; and we say without hesitation that if the War

Office will rest content to make its guns of steel with a minimum limit of thirty tons and a maximum of thirty-two tons, and an elongation of twenty per cent., there will be no more broken guns—always provided, of course, that the gun is properly proportioned to the nature of the powder to be burned in it.

"We have said that the authorities possibly adopt a hard steel for a special reason. This reason is that it is assumed—we are not aware that it has ever been proved—that soft steel scores so fast as soon to render a gun useless. Whether this is so or not, the true remedy does not lie in using hard steel; or rather the remedy is much worse than the disease. Unless soft, tough steel is employed in guns, the results must be disappointing. It is all very well to talk of oil-tempering and so on. Such treatment may mitigate the evil, it will not remove it. . . . . .

"In any case, if the use of hard steel is to be persisted in, then it must have the form of a comparatively thin tube, which can be taken out without much trouble in case of failure, and this tube must be covered from end to end with one, if not two, other tubes of soft steel. Knowing, however, as much as we do of steel, we repeat that the use of any steel with a higher tensile strength than thirty-two tons, or at the outside thirty-three tons, to the square inch, is a serious mistake, and so long as it is persisted in, so long shall we continue to hear of failures of guns; and it must not be forgotten that such failures need not all be of the Collingwood or Active type. We may have the chases split or cracked without the complete breaking up of the gun; and we shall not be wrong if we assert that the occurrence of failures of this kind is very far from uncommon. It is not confined to the guns of Great Britain—the guns of all nations are liable to fall victims. Hard steel is no respecter of persons or nations. Engineers know it to be a treacherous material; and artillerists will do well in this matter to profit by the experience which engineers have acquired with much trouble and vexation of mind and at an enormous expense."

This is a very emphatic endorsement of my views.

The *Engineering* of London, also very high authority on engineering and mechanical matters, in its edition of September 24, 1886, says in reference to the Collingwood accident: "In relation to guns, no further argument is needed to tell us that some better method than the one now in use must be found for the supply of the Army and Navy." In reference to the report of the committee appointed to investigate the cause of the bursting of the 12-inch gun on the

Collingwood, it says: "They find that the metal in the chase was irregular in its character, and as such it would be specially liable to the setting up of internal strains during the process of forging and oil-hardening." This is a very true definition of the character of all open-hearth hard steel.

In its issue of October 1, 1886, in reference to "Big Guns," it says: "More than this, our War Office is not even in possession of designs that combine efficient material with simplicity of form and economy of manufacture." *Engineering* thinks that the plans of the English War Office are incorrect and unsafe. It advocates thorough experiments in the following strong language: "But this question cannot be decided on paper, nor by discussion. It is only by experiment such as we have proposed that practical results can be obtained. The sooner we commence, and the more comprehensive we make them, the earlier will come our feeling of security."

These extracts from the two leading mechanical and engineering papers of England show that, notwithstanding their long experience and heavy outlay in money, the gun question is still unsettled, and they must experiment in order to find out the best gun and material to adopt. The opinions seem to be very decided against the use of hard steel.

The *American Manufacturer and Iron World*, good authority on iron and steel, in its edition of December 3, 1886, in reference to guns, says: "The time has finally come when our Government should abandon definitely and forever its costly experiments with 'built-up' guns made on the absurd and unscientific European system now in vogue. The evidence of the absolute non-reliability of guns made on this system, even by the best makers, is overwhelming. The English Ordnance Board report, concerning the bursting of the Collingwood's 43-ton gun, that this gun 'would be specially liable to the setting up of internal strains during the processes of forging or of oil-hardening.' Relative to the *material* in the Krupp guns, Col. Hennebert says: 'During the war of Bohemia several fieldpieces burst. After the war, in order to allay public agitation, trials *à outrance* were made, and these cost several young officers their lives. In 1868, General de Bœuf declared that several guns firing ordinary charges had burst; nor can it be said that the Prussian steel guns of to-day are safe. In fact, between 1867 and 1870 numerous accidents occurred in Russia, England, Germany, and Italy, on land and on board ship.' Colonel Hennebert says that during the Franco-German

war 200 Krupp guns burst, as mentioned by Major Haig in a report read before the Royal Artillery Institution, and by the Duke of Cambridge in a speech in the House of Lords on April 30, 1876: 'Out of seventy heavy guns employed against the southwest of Paris, thirty-six were disabled during the first fortnight of the bombardment by the effect of their own fire. At Versailles it was thought that if the French had held out a week longer, the German siege batteries would have been reduced to silence. It is evidently certain that during the campaign on the Loire, Prince Frederick Charles had twenty-four of his guns disabled by their own fire.'

"This is what might have been expected. Every steelmaker who is not a gunmaker says these large masses cannot be forged so as to be safe from injurious strains.

"Every mechanic who is worthy of the name knows that such masses of rings and tubes cannot be fitted and assembled so as to act as a continuous whole, and even if they were so fitted they could not be retained in that condition after the warming up of the first few rounds."

The *Engineering and Mining Journal* of New York, one of the highest metallurgical authorities, in a recent number says:

"IS HARD STEEL SUITABLE FOR HEAVY GUNS?

"The question of hard or soft steel in cannon has for some time attracted the attention of engineers, especially since the recent bursting of some of the English naval guns, although the experience of Germany and France in the Franco-German war had already demonstrated a very large proportion of failures among guns made of this metal.

"Since the very introduction of steel for structural purposes, engineers have found it necessary to use only low-carbon or mild steel; for it was early found that hard steel was brittle and incapable of resisting shocks. Take, for example, such uses as for shipbuilding, for bridges, for locomotive tires, for roll shells in crushing ore, for jaw plates in rock-breakers, and generally for uses where sudden and heavy blows or vibrations are to be expected.

"It is true we yet know very little concerning the reasons why hard steel, capable of resisting extremely high tensile strains, should break under comparatively light shocks; but the fact is perfectly recognized, nevertheless, and in all works where the contractor is held by business interest or direct specification to secure a durable structure of steel,

he would not think of adopting the hard metal. It seems incomprehensible, therefore, that in guns, where the jar and vibration are probably greater than in any other engineering use, Government engineers should have adopted a metal that has long been condemned and rejected by civil engineers in all uses where the conditions are analogous."

The *Engineering News and Contract Journal* of New York, which deservedly stands very high as an engineering journal, in reference to guns, says in a recent issue:

"Many prominent engineers and steel-workers agree with the author that hard steel, made by the open-hearth process, and as called for in the specifications of the U. S. Ordnance Bureau of the Army and Navy, cannot be considered a safe material for heavy guns; at least with our present knowledge of its properties. In fact, we consider this material utterly unreliable when used in the great masses called for by the size of modern guns; and in this we are supported by some of the best engineering authorities in the countries where guns so made have already been tested and practically found wanting.

"A material rejected by bridgebuilders and boilermakers because of its unreliability under sudden stress, is certainly not the stuff to put into guns that are supposed to successfully resist the most abrupt and violent of shocks to which the materials of construction could possibly be subjected."

The preceding extracts from the leading engineering and mechanical papers of England and the United States are very decided against the use of hard steel for constructing guns.

In the early days of steel, and before mild steel was commercially known, small guns were made from hard steel and found to answer well. Since then the size of guns has very largely increased, and ordnance-makers have continued to use the same material for the construction of the large as they did for the construction of the small guns, ignoring entirely the discovery of mild steel—a much more reliable and cheaper material. They also seem to have overlooked the fact that the difficulty and cost of working and forging hard steel are increased very rapidly with the size.

It is not fair to blame our ordnance officers for this, as they have been so stinted in appropriations that they have not been able to experiment for themselves, and in the absence of these experiments they were obliged to adopt the practice of foreign countries—especially

England. The English adopted a certain class of steel for small guns twenty-five years ago, and with their usual conservatism they have adhered to it up to the present time, making from it alike large and small guns.

Civil engineers made the same mistake, using hard steel at the commencement with high tensile strength, but by the failure of their work they soon learned to use mild steel—about two-thirds of the tensile strength they used at first.

Congress should give our ordnance officers ample means to make their own experiments and tests, and not oblige them to follow the practice of foreign countries.

In order to settle knowingly the gun question, a commission should be appointed consisting of Army and Navy officers and civil engineers, Congress giving them ample power and means to buy for experimenting purposes the best make of guns, both foreign and domestic, including cast-iron and cast-steel. Let these be equally subjected to the same severe fire of small guns and machine guns as they would be in actual service. After this test them to destruction, giving to each the same amount of good and bad treatment. "The survival of the fittest" will show us the type and model we must adopt for our guns.

This commission, composed as above stated, would have the united knowledge and experience of the three professions.

These experiments, in order to be thorough and complete, must necessarily be very expensive; but it will be money well spent, as it will be the means of giving us good and serviceable guns. Otherwise, by our present policy, we will spend several hundred millions of dollars on guns that may be found useless in the hour of trial; probably many doing more harm to our officers and men than to the enemy.

# BIBLIOGRAPHIC NOTES.

AMERICAN GEOGRAPHICAL SOCIETY BULLETIN.

No. 3. The war in the Soudan for the rescue of "Chinese Gordon," by General R. E. Colston, Washington, D. C.

AMERICAN PHILOSOPHICAL SOCIETY.

DECEMBER, 1886. On the economatic method of phonetic writing, etc., by Daniel G. Brinton.

AMERICAN SOCIETY OF CIVIL ENGINEERS, TRANSACTIONS.

AUGUST, 1886. On the work done for preservation of the dam at Holyoke, Mass., etc.

SEPTEMBER, 1886. Evaporation, by Desmond Fitzgerald.

OCTOBER, 1886. The cause and prevention of decay in building-stone, by Thomas Egleston. Discussion.

ASSOCIATION OF ENGINEERING SOCIETIES, JOURNAL OF.

DECEMBER, 1886. The velocity of light in air and refracting media, by Professor Albert A. Michelson.

COMPETITIVE TRIALS OF CHRONOMETERS 1884 AND 1886.

Appendix III of the Washington Observations for 1883, recently issued, contains a collection of papers embracing a description of the temperature-room used at the Naval Observatory for chronometer-testing, and an account of the competitive trials of chronometers in 1884 and 1886. The Appendix is in the shape of a report of the Superintendent, Allan D. Brown, U. S. N., to the Chief of the Bureau of Navigation.

The first part is a reprint of the paper by Lieutenant E. K. Moore, U. S. N., entitled "Method of Testing Chronometers at the U. S. N. Observatory," originally published in the *Institute Proceedings*, Vol. X, No. 2. Next follows a reprint of "Competitive Trials of Chronometers at the U. S. N. Observatory," by the same author, *Proc. U. S. N. Inst.*, Vol. XI, No. 1. The new matter includes a paper by Lieutenant E. C. Pendleton, U. S. N., who describes the last competitive trial, and a description of changes in the arrangement of the temperature-room by Commander Brown, with a plate showing the ingenious construction of the gas-tight automatic valve through which the fuel (gas) for heating is supplied and cut off.

The Appendix presents in a compact form the present state of knowledge regarding the effect of both temperature and humidity on the chronometer, as well as the steps in the investigation of these influences at the Naval Observatory.

As such it is an interesting and valuable contribution to the literature of the subject.

A few points may be briefly referred to:

It is a subject for congratulation that the art of chronometer-making has so

advanced in our country that the restriction can be imposed that no chronometers but those of American manufacture shall be admitted to these competitive trials, and that the makers are willing and anxious to compete.

The work of the officers having charge of the chronometers at the Naval Observatory has proved incidentally that research is well expended in the attempt to improve our present instruments of navigation, and that such research affords a field where the scientific attainments of our officers can well and profitably be employed. The work of the authors of the above papers is in worthy succession to the previous labors of Lieussou, Hartnup, Davis, and of other investigators.

As is well known, the influence of a varying temperature on a carefully kept chronometer has an effect greater than that of any other influence. This effect having become measurable by the refined processes of the Observatory, the effect of a varying humidity has also been studied.

The impression is prevalent that chronometers follow a fixed law with a variation of the humidity. The last trial of chronometers, however, proves that no hard-and-fast rule can be laid down, some chronometers gaining while the humidity was increased, others losing. "The only thing that can be said, then, of each of these individual instruments is that with an increase of humidity it will *probably* gain or lose, as shown by this test." Even such a statement, it is plain, must be vastly superior to a general assertion, as sometimes seen in print, that chronometers will gain on their rate when the humidity decreases, and lose when it increases.

In this connection it will be found interesting to consider the remarks on the effect of a humidity short of saturation contained in the report of the Superintendent for the year ending June 30, 1886, page 7. As an additional safeguard against chronometers rusting, it is suggested that "each chronometer be supplied with a baize cover, to be kept on it at all times when the instrument is not in use; a second one should be provided, and in wet weather the cover should be changed daily and dried at the galley." A. G. W.

ENGINEER.

NOVEMBER 5, 1886. Particulars of armored vessels.

| | Immortalité. | Mersey. | Hero. | Benbow. |
|---|---|---|---|---|
| Length between perpendiculars | 300 feet. | 300 feet. | 270 feet. | 330 feet. |
| Breadth (extreme) | 56 feet. | 46 feet. | 58 feet. | 68 feet 6 inches. |
| Displacement | 5000 tons. | 3550 tons. | 6200 tons. | 10,000 tons. |
| Engine | Horizontal direct-acting. | Vertical direct-acting. | Horizontal direct-acting. | Inverted direct-acting. |
| Horse power | 8500. | 6000. | 6000. | 7500. |
| Size of cylinders | 36-inch H. P.<br>51-inch intermediate.<br>78-inch L. P. | 38-inch H. P.<br>64-inch L. P. | 42-inch H. P.<br>84-inch L. P. | 52-inch H. P.<br>74-inch L. P. |
| Stroke | 3 feet 6 inches | 3 feet 3 inches. | 3 feet. | 3 feet 9 inches. |
| Boilers, heating surface | 15,472 square ft. | 11,771 square ft. | 14,224 square ft. | 20,244 square ft. |
| Grate surface | 486 square feet. | 399 square feet. | 507 square feet. | 800 square feet. |
| Pressure | 130 pounds. | 110 pounds. | 84.5 pounds. | 90 pounds. |
| | Armament.<br>Guns: 9 2-in. B L No. 2; 6-in 89-cwt. B.L. No. 10.<br>Also to be fitted with quick-firing and machine guns and Whitehead torpedoes. | Armament.<br>Guns: 8-in. B.L. No. 2; 6-in. 81-cwt. B. L. No. 10.<br>Also to be fitted with quick-firing and machine guns and Whitehead torpedoes. | Armament.<br>Guns: 12-in. 43-ton B. L. No. 2; 6-in. 89-cwt. B. L. No. 4.<br>Also to be fitted with quick-firing and machine guns and Whitehead torpedoes. | Armament.<br>Guns: 110-ton B. L. No. 2; 6-in. 89-cwt. B.L. No. 10.<br>Also to be fitted with quick-firing and machine guns and Whitehead torpedoes. |

NOVEMBER 19. Editorial calling attention to the great and unaccountable condensation of steam in the H. P. cylinder and jacket of compound engines.

In one case it appeared that 13 square feet of steam cylinder was as efficient for condensing purposes as two square feet of small tubes immersed in water, and that one square foot of jacket was about equal to five or six square feet of condenser tubing.

DECEMBER 3. On the manufacture and use of wrought-iron castings.

Good wrought-iron scrap is melted in a petroleum furnace in crucibles, and when just fluid .05 or .1 of one per cent. of aluminum is added. This lowers the melting-point about 400°, gives fluidity sufficient for casting, and at some time liberates gases previously absorbed. The product is uniform in quality and equal to the best wrought iron; can be welded and forged; the tensile strength is twenty to fifty per cent. greater than that of the raw material.

DECEMBER 10, 1886. Particulars of a trial of torpedo boat No. 79, the speed of which surpassed that attained by any other similar craft in the English service.

Length of boat, 125 feet; beam, 13 feet; mean draught, 3 feet 4 inches; load carried, 10 tons. Turning circles, going ahead: to port, 80 yards diameter in 59 seconds; to starboard, 90 yards diameter in 57 seconds. Going astern: starboard, 70 yards diameter in 70 seconds; to port, 60 yards diameter in 60 seconds. Vibration, practically none.

| Steam. | Receiver. | Vacuum. | Revolutions per minute. | Time. | Speed. |
|---|---|---|---|---|---|
| Lbs. | Lbs. | Ins. | | H. M. | Knots. |
| 139 | 59 | 26 | 411 | 2 42 | 22.22 |
| 139 | 60 | 26 | 410 | 2 31 | 23.84 |
| 140 | 60 | 26 | 400 | 2 32 | 23.68 |
| 140 | 60 | 26 | 398 | 2 54 | 20.68 |
| 140 | 60 | 26 | 404 | 2 30 | 24.00 |
| 140 | 62 | 26 | 403 | 2 52 | 20.93 |
| 140 | 62 | 26 | 401 | 2 30 | 24.00 |
| 140 | 62 | 26 | 401 | 2 53 | 20.80 |

[*Note.*—Mean of last six runs made over measured mile alternately with and against the tide is 22.39 knots.] W. F. W.

DECEMBER 17, 1886. Trial of the Spanish twin-screw torpedo cruiser Destructor.

Displacement of vessel, 350 tons; total I. H. P. of both engines, 4000; mean speed for four consecutive hours, 22.65 K.; mean speed for four consecutive hours in heavy sea-way, 22 K.; revolutions per minute, 350; coal supply sufficient to steam 700 K. full speed; coal supply sufficient to steam 5100 K. at 11½ K. The four boilers, of locomotive type, worked without priming or leaking, with forced draught of two inches. The time required to turn a complete circle less than three times the ship's length was one and three-quarter minutes. W. F. W.

### *Table Showing the Relative Efficiency of Different Types of Engines.*

[Taken from "Die Schiffsmaschine."]

| Type of Engine. | Most advantageous number of times to expand the steam. | Pounds of coal required per hour per I. H. P. when working most economically | Pounds of water required per hour per I. H. P. when working most economically. | Relative efficiency of the different types of engine, each cutting off at its most economical point. |
|---|---|---|---|---|
| 1. Newest compound engines with great piston speed and high steam pressure. [Date of publication of the data 1883] ......... ......... | 10 | 1.8 to 2.2 | 18 to 21 | 40 |
| 2. Older compound engines with lower piston speed and lower steam pressure............ | $6\frac{2}{3}$ | 2.2 to 2.6 | 21 to 25 | 36 |
| 3. Compound engines working with 60 pounds steam pressure, surface condensers, steam jacket, and superheated steam............... | 4 | 2.6 to 3.1 | 25 to 29 | 30 |
| 4. Simple engines with 45 pounds steam pressure, surface condensers, steam jacket, and superheated steam. ......... ............... | $2\frac{3}{4}$ | 3.1 to 3.5 | 27 to 31 | 26 |
| 5. Simple engines with jet condensers, without steam jacket and without superheated steam.................................................. | $2\frac{1}{2}$ | 3.5 to 4.4 | 31 to 36 | 24 |
| 6. Old simple engines with less than 45 pounds steam pressure, with jet condenser, and without steam jacket or superheated steam | $1\frac{2}{3}$ | 4.4 to 5.5 | 36 to 40 | 20 |

ENGINEERING.

November 19. Article on the German Navy from a Spanish official document giving the plan of organization, description of ships and torpedo boats and system of coast defenses, etc.

December 17, 1886. Particulars of H. M. S. Narcissus, just launched.

Length, 300 feet; beam, fifty-six feet; draught, twenty-one feet; expected speed, nineteen knots. Steel-faced armor belt ten inches thick, backed with 6-inch teak; two hundred feet long, extending one foot six inches above to four feet below water-line. On level with top of this is the protective deck of 2-inch steel in wake of armor, and three inches thick, inclined at 30° towards ends of ship outside of belt. Conning tower has 12-inch steel-faced armor. Armament, one 10-inch breechloader in citadel, with ten 6-inch guns. Between decks are ten Hotchkiss and two 9-pounders. There will be two jury masts with fighting tops. Engines, horizontal, direct-acting, triple-expansion; diameters of cylinders, thirty-six inches, fifty-one inches and seventy-eight inches; stroke, forty-two inches; condensers of brass with 12,000 square feet cooling surface; pumps and connections, gun metal; two double-ended steel boilers fourteen feet six inches diameter by seventeen feet six inches long, with corrugated furnaces; pressure, 130 pounds; propellers of gun metal fourteen feet six inches diameter. W. F. W.

GIORNALE D'ARTIGLIERIA E GENIO.

No. 8, 1886. Inspection and proof of gunpowder, with plates.

INSTITUTION OF MECHANICAL ENGINEERS, LONDON.

No. 3. Experiments on steam-jacketing and compounding of locomotives in Russia, by Mr. Alexander Boradin. On the working of compound locomotives in India, by Mr. Charles Laniford.

JOURNAL DU MATELOT.

No. 42.

The Dupuy-de-Lome has been commenced at Brest, and the Jean Bart at Rochefort. They are steel cruisers of the first class, with barbette towers, after the plans of M. Thibaudier. The principal characteristics are: Water-line length, three hundred and fifty-three feet three inches; beam, forty-three feet eight inches; depth, thirty feet six inches; least draught, eighteen feet nine inches; displacement, 4162 tons; speed, nineteen knots. Armed with four 16-cm. and six 14-cm. guns, six revolving cannon 37 mm., four rapid-fire guns 47 mm., and four tubes for torpedoes. The engines, boilers and other vulnerable parts are protected by a steel shield.

No. 46. "Maritime Experiments for 1886," a book published by Berger, Levrault & Co.

Its contents are: First experiment against the Protectrice with a submerged torpedo. Experiments in the Mediterranean with a fleet of ironclads and a fleet of torpedo boats, comprising all sorts of manœuvres; as, the bombardment of Toulon, defended by torpedo boats: the attack fell through, the blockade being forced, although there were eight ironclads. The passage of Cape Corsica effected, although with much loss to the ironclads, and the passage could have been prevented with a sufficient number of torpedo boats. Torpedo boats forced their way into Ajaccio, notwithstanding very bad weather, and spread disorder amongst the ironclads. Finally a squadron from Africa tried to force a passage through the Balearic Islands, but a small number of torpedo boats (after being at sea several days) did the squadron much harm. All this going to show that the torpedo boat is a terrible engine and will play an important part in future wars. D. H. M.

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION.

June 18, 1886. On the use of petroleum as fuel in steamships, etc.

The following information is obtained from a paper read and the subsequent discussion: The fuel used in Russia is a product of petroleum called "astatki," obtained by distilling the crude oil in iron boilers. The first products are benzine and gasoline, then kerosene and solar oil; all oil between .78 and .86 specific gravity being considered kerosene. This is a much higher specific gravity than American oil. The oil of specific gravity .86 to .88 is called solar oil. The remainder is called astatki, having generally the specific gravity .91 and higher. The burning-point of this is about 422°F. The astatki is injected into the furnace with a jet of steam or air, and its use is perfectly practicable. The number of vessels, including small tugs and steam launches, which use it on the Volga and Caspian Sea is estimated at not less than 200. Some of these have been using it for the last fifteen years. One of them has made 250 voyages. There are also a few steamers on the Black Sea using astatki, and two or three building in England to carry petroleum as freight will also burn it as fuel. Moreover, astatki is used at all the factories at Baku (about 100),

numerous factories on the Volga, some at Moscow and one at St. Petersburg, and more than 500 locomotives.

Comparing astatki with coal, the former has theoretical evaporative power of 16.2 pounds of water per pound of fuel, and the latter 12.2 pounds at 120 pounds steam pressure; hence astatki has, weight for weight, thirty-three per cent. higher evaporative value than anthracite. In locomotive practice a mean evaporation of seven to seven and a half pounds of water per pound anthracite is about what is generally obtained, thus giving in the case of coal about sixty per cent. efficiency, but with astatki an evaporation of 12.25 pounds is practically obtained, giving seventy-five per cent. efficiency. Weight for weight, the value of astatki is reckoned at $\frac{12.25-7.50}{7.5}=63$ per cent. to $\frac{12.25-7}{7}=.75$ per cent. higher than coal; that is, one ton of astatki is equal in practical efficiency for steam-generating purposes to about one and three-quarter tons of the best anthracite when the steam jet is used, and better results are obtained with air. The advantages in its use are:

(1) The stowage space for equal weights is less than coal in ratio of 38 to 45.

(2) It can be stowed in places not available for coal (between inner skin, etc.).

(3) Can be pumped on board at rate of 100 tons per hour and even faster.

(4) There is no ash, refuse or smoke.

(5) It requires no stoking or attention. Russian steamers on the Caspian run from port to port without attention to fires, and on these steamers only men enough are employed to keep the machinery clean.

(6) It can be supplied to furnaces from the bunkers with much greater facility than coal.

(7) It can be taken aboard from another steamer at sea.

With regard to cost. The price of astatki at present at Baku (on the Caspian Sea) is 2s. 6d. per ton. At Batoum (on the Black Sea) it is about 25s. per ton, which will probably be reduced to 17s. when the contemplated pipe line is finished. The cost of crude petroleum at Philadelphia (U. S.) is about 74s. per ton. The quantity of refuse fit for burning produced at Baku is very much greater in proportion to the crude oil than it is in America. In the United States about seventy per cent. of kerosene is obtained, while at Baku only thirty per cent., leaving a residue of seventy per cent. for fuel. Also, in the United States the residue is used for the production of anthracene, naphthalene and benzol, still further reducing the quantity available for fuel. W. F. W.

*Note.*—Mr. Martell, of Lloyd's, in course of the discussion, gives the cost of the best coal in England as eight shillings or ten shillings per ton, and freight to Batoum about fifteen shillings. This would make the cost of the best English coal in Batoum about twenty-three to twenty-five shillings per ton. Also, it appears that there are only a few steamers on the Black Sea using astatki at the *same price* (twenty-five shillings per ton), with the prospect of that price being soon reduced to seventeen shillings. Hence we may infer that the other advantages of astatki over coal are not so great or so obvious as the statements given in the paper and discussion would lead us to believe. It is to be noted that the cost of crude petroleum quoted in the discussion, and often used as the basis of an argument against the use of petroleum, is not relevant to the question, because, on the one hand, the crude oil cannot be safely stowed on a ship, and, on the other hand, no idea can be formed of the value of the by-products by simply considering the cost of the crude material. By distillation the products obtained in Pennsylvania are about as follows: Naphthas, sixteen and one-half per cent.; kerosene, seventy per cent.; loss, eleven and one-half per cent.; residue, two per cent. The naphthas are too explosive to be stowed with safety. The average wholesale price of kerosene for the year

1886, the lowest ever reached, was 7.07 cents per gallon, or $24.75 per ton of 2240 pounds (see Annual Statement New York Shipping and Commercial List, 1886). Hence this is excluded by cost. It only remains to inquire about the two per cent. residue. In order to obtain trustworthy information on this point, a letter was addressed by me to the Secretary of the Standard Oil Company, New York, and referred by him to the Pratt Manufacturing Company, New York, who kindly furnished the required information. The specific questions asked were: "1st. Can you produce a by-product from petroleum similar to the Russian astatki, and which you can sell for about $5.00 per ton? 2d. Could you supply that product in quantities of, say, 1000 tons per annum?" The answer was: "*We produce nothing from petroleum but what has a greater value than the price you name.* Some of the smaller manufacturing establisments about New York use by-products of petroleum as fuel for special reasons, entirely outside of economy. The current price of these products is from three to three and one-half cents per gallon (*i. e.* $10 to $12 per ton)." W. F. W.

MECHANICAL ENGINEER.

NOVEMBER 27, 1886. Side elevation of engines of the 1700-ton new United States gunboat, with description. Table showing the evaporative power of pea, egg, and soft coal, and that the first is much the best for steam boilers, taking into account its present market value. Table of fifty-five steamships plying between New York and European ports, showing their tonnage and principal dimensions.

DECEMBER 11. Sketch and description of piston valves of new cruisers. W. F. W.

PROCEEDINGS OF THE CANADIAN INSTITUTE, TORONTO.

NOVEMBER, 1886. The archæological outlook. Classical notes. The law of habit. Rent—a criticism. The village community in modern politics. New England Upper Silurian. Etruria capta. Hypnotism. Mechanical value of coal. Analogy between consonants and musical instruments. The Eskimo of Stupart Bay. Gneissic foliation. Savagery in civilization. The mound builders in Canada. Aërial navigation. The last paper was an exhaustive treatise on the history of ballooning, by Alan Macdougall, M. I. C. E., F. R. S. E. The conclusion was that, so far as any success had been attained, it was more in the scientific than in the commercial solution of the problem. The number of lives which have been lost of late years is not compensated by any progress made in the practical solution of aërial navigation. P. F. H.

PROCEEDINGS OF THE SOCIÉTÉ DES INGÉNIEURS CIVILS.

JANUARY, 1886. Proposed plans of a bridge across the Douro River at Oporto.

FEBRUARY, 1886. Mathematical study of the action of propellers upon the water, and their construction. Use of compound engines on steamships, and reasons why multiple expansion cannot be advantageously used above certain limits.

MARCH, 1886. Comparative strength of iron and steel.

APRIL, 1886. Description of locomotive engine constructed by Bontel et Cie., of Paris, designed for a speed of sixty or seventy miles an hour.

MAY, 1886. Mathematical papers on the calculation of dimensions of machinery capable of producing currents of given strength and electro-motive force, and on the distribution of energy in dynamo-electric machines. Plans proposed for improving the channel at the mouth of the Seine and of the harbor of Havre.

JUNE, 1886.

JULY, 1886. Additional plans for improving channel at the mouth of the Seine.

AUGUST, 1886. S. M.

RÉUNION DES OFFICIERS.

NO. 42. OCTOBER 16, 1886. Recruiting for the Navy. Law of July 22, 1886.

NO. 44. OCTOBER 30, 1886. The three classes of torpedo boats. Estimates for construction of new vessels, 140 millions of francs, with 60 millions for other expenses not less necessary, such as different navy yards, ports of refuge and concentration; submitted by the Minister of the French Navy. A new cooking-apparatus for the Army.

NO. 46. NOVEMBER 13, 1886. An article on experiments with the repeating rifle. Vitali's system as used in Italy.

NO. 47. NOVEMBER 20, 1886. An interesting article on military roads, containing a map of Paris and environs, showing the railroads, stations, etc.; also the plan for a great union depot to be erected near the Trocadero. An article on repeating rifles; experiments carried on in Austria with the Mannlicher system; in Belgium with the Remington-Lee system, which has excited much interest in Belgium.

NO. 48. NOVEMBER 27, 1886. Experiments with repeating rifles in Italy with Vitali's system, which has been adopted to the exclusion of all others.

In Portugal the rifle manufactured by Steyr, of Austria, has been adopted; the system is that of Kropatchek; 40,000 have been ordered. In this article there is much good reading as to the repeating rifle treated as an arm for attack and for defense. Also, an interesting article on cavalry raids, citing Stuart's famous raid into Pennsylvania. The *Bulletin de la Réunion des Officiers* ceased to exist with this number, and on December 4, 1886, was published, in its stead, the first number of the *Revue du Cercle Militaire, Armées de Terre et de Mer*. D. H. M.

REVUE DU CERCLE MILITAIRE.

NO. 1. DECEMBER 4, 1886. An article comparing the power of artillery as against infantry. Also, The next Franco-Prussian war, by Colonel Von Kätschau.

NO. 2. DECEMBER 11, 1886. Ending of article on Artillery *versus* Infantry. Continuation of Colonel Von Kätschau's article.

No. 3. December 18, 1886. End of Colonel Von Kätschau's article. The organization of columns of attack, looking to the destruction of obstacles accumulated by the defending party. The special military school at Saint Cyr (1808 to 1812). D. H. M.

REVUE MARITIME ET COLONIALE.

November, 1886. The budget of the French Navy. The Legion of Honor. Determination of submarine currents. The advantages of the electric light for the interior of vessels. Filters acting by ascension. Reconstruction of the Navy of the United States.

December, 1886. Elementary theory of the movement of the top, and its application to the artificial horizon. The gyroscope-collimator. Substitution of an artificial mark for the sea horizon. The budget of the English Navy. Naval Chronicle. English Navy: The Impérieuse, the Forth, the Tartar; trial of the Benbow. Russian Navy: The first-class cruiser Rynda. Swedish Navy: The ironclad Svea. Artillery: The Hope cannon; the Firminez shell; the new explosive, Silotvaar; the new rubber composition sheathing called Woodite, from the name of the inventor, Mr. A. M. Wood. Torpedo vessels: The Brennan torpedo. An official trial of the Brennan torpedo took place at Sheerness on October 26, 1886. Torpedo boat No. 69, having a small target in tow, was started from Sheerness at full speed, and the torpedo was discharged from Garrison Point by Mr. Brennan himself against the target. This was struck while being dragged at the rate of sixteen knots an hour. The Brennan torpedo is from six to nine metres long and weighs about a ton. It is completely under the control of the operator on shore. At night its course is indicated by a small light produced by chemical action, and having a screen in front. It is said that this torpedo has been adopted for the defense of the English coasts. The inventor is an Australian. B. F. T.

RIVISTA DI ARTIGLIERIA E GENIO.

October, 1886. The attack and defense of fortified places (conclusion). Cannon of manganese bronze. R. C. S.

RIVISTA MARITTIMA.

October, 1886. The Italian merchant marine (conclusion). General index for the years 1868–1885 inclusive. Rome, 1886.

October, 1886. The Volta, boat propelled by electricity.

On the 12th September this boat made the trip from Dover to Calais. It is of steel, thirty-seven feet long, six feet ten inches beam, and has a storage battery of sixty-one cells, and two Reckenzann electric motors, which act on the same shaft. By moving a crank the boat can be made to go at slow, medium, or full speed, or can be stopped or started without touching the storage battery. By another crank the motion of the machine is reversed by simply changing the direction of the current in the armature. The motors are placed in the stern

directly over the keel, and occupy a space of three feet ten inches long, one foot nine inches wide, and twelve and a half inches high. They weigh 730 pounds, and develop a maximum horse power of sixteen at the crank. The propeller is three-bladed, twenty inches diameter, eleven inches pitch, connected directly with shaft of motor. It makes at minimum velocity about 600 revolutions per minute, and at maximum velocity about 1000.

The storage battery weighs about two tons, and is placed along the keel under a wooden deck. On the day of the trial the cells were charged by means of a dynamo on shore at Dover. The E. M. F. at the start was 120 volts at twenty-eight ampères. The boat left the quay at Dover at 10.41 A. M. and reached Calais at 2.32 P. M., thus requiring three hours and fifty-one minutes for the trip; but it did not pursue a direct course. The trip was made at reduced speed (about 600 revolutions per minute), to economize the current to make sure of being able to return. On being tested at Calais, the battery measured twenty-eight ampères, as at the start. During the passage the boat moved smoothly and quietly, with a speed of about seven miles per hour. On the return, which was also made at reduced speed, the boat left Calais at 3.14 P. M. and reached Dover at 7.37, requiring four hours and twenty-three minutes. The current remained constant at twenty-eight ampères until 5 P. M., but at 6 P. M. it had fallen to twenty-five, and on arrival at Dover it was twenty-four. Nevertheless, on approaching Dover there remained sufficient motive power so that the last half mile was run at full speed (1000 revolutions), and the speed of the boat was about fourteen miles per hour. W. F. W.

UNITED SERVICE GAZETTE.

OCTOBER 23, 1886. Is England ready for war? a paper embodying the substance of a memorandum which has recently been presented to the Board of Admiralty, by Lord Charles Beresford, Junior Lord of the Admiralty.

The Forth, second-class steel steam cruiser with twin screws, was launched at Pembroke, October 23. She is a vessel of 3550 tons, 5700 horse power, and will carry twelve guns. Her keel was laid down December 1, 1884.

OCTOBER 30. Coaling stations.

The Lords of the Admiralty, with the view of encouraging scientific study at the Royal Naval College, have been pleased to sanction the following prizes, which are to be awarded at the close of each session—viz.: One prize of £100 for general proficiency; two prizes of £80 each for gunnery and torpedo lieutenants gaining the highest marks in their respective courses.

NOVEMBER 13. The late Admiral Hobart Pasha. The Chatham dockyard. Establishment of the "Distinguished Service Order" by the Queen.

NOVEMBER 20. Abstract of French naval estimates.

Count Bylandt, Austro-Hungarian Imperial Minister, has announced that the Mannlicher repeating rifle of eleven millimetres radius of barrel, and firing eighty shots a minute, will be adopted.

NOVEMBER 27. The Royal Naval Artillery Volunteers. Abstract of memorial accompanying German naval estimates.

With a view of training seamen in the management of torpedo boats, directions have been issued by the Admiralty for No. 4 torpedo vessel to be attached to the Medway Steam Reserve for instructional purposes.

DECEMBER 4. Lord Brassey on the Navy.

The gunboat built at La Seyne, which has attracted so much attention in France, has the following dimensions: Total length, 41 metres; beam, 3.8 metres; weight of hull, 26.8 tons; weight of motive machinery (compound 560 horse power), 22 tons; weight of gun and carriage, 11.5 tons. The vessel is divided into nine water-tight compartments, and at her trials attained a mean speed of 19.2 knots. She has the shape of a torpedo boat, possesses great nautical qualities, is swift and almost invisible, and is built with great strength in order to withstand the discharge of the 14-centimetre gun which forms her only armament. This piece is protected by a steel-plate screen against an enemy's projectiles. The vessel cost $53,000.

Trial of a new submarine boat.

DECEMBER 11. Mr. Forwood's remarks about the English Navy. The Royal Military Academy at Woolwich.

On Tuesday, December 7, at Spithead, H. M. S. Edinburgh made a trial of her four 45-ton breechloading guns. Considerable interest attaches to the testing of these 45-ton guns, which have superseded the old 43-ton pattern, the Collingwood explosion having proved them to be too weak at the chase and necessitating them being hooped to the muzzle. Six charges were fired from each 45-ton gun with satisfactory results.

DECEMBER 18. Gunboat Warfare, by Admiral Sir George Elliot, R. N. Quick-firing guns in field operations.

The trial of the new hydraulic gun-mounting for the 68-ton 13.5-inch Woolwich guns which are to be mounted in the barbette ships of the Admiral class commenced on board the Handy, off Shoeburyness, December 13, under the direction of Captain Dornville and the officers of the Excellent. The programme consisted of a scaling charge and twenty rounds, of which eight were with a reduced charge of 423¾ pounds of brown powder, and twelve with the full charge of 565 pounds (the largest charge ever fired in a naval gun in England, being nearly twice the full charge of the 45-ton guns), the projectile in each case weighing 1250 pounds. Owing to misty weather, only four rounds were fired on the 13th, but the remaining sixteen rounds were concluded on the following day, the hydraulic mounting and breech mechanism behaving to the complete satisfaction of the officers present.

DECEMBER 25. The Fleet, poem by Lord Tennyson. The coming war.

On Monday, December 20, Lord George Hamilton, First Lord of the Admiralty, Captain Fisher, Director of Naval Ordnance, and other officials connected with the Admiralty, made a trip in the new torpedo boat No. 79, which has just been completed by Messrs. Yarrow & Co. Special interest attaches to this boat, owing to the fact that it is not only the fastest vessel in the British Navy, but is also the most rapid in manœuvring. At the official trial the speed attained during a two hours' continuous run was 22.4 knots per hour, and when going ahead the boat is capable of being turned in a circle the radius of which is about equal to her length. In the construction of torpedo boats it appears that it is an easy matter to obtain speed without steering power, or steering power without speed; but to combine the two qualities has always been difficult. Messrs. Yarrow have attained a great success in this No. 79. As a general description of the boat, it may be said that she is fitted with two turrets, from either of which she may be steered. Working round each turret are two torpedo guns for firing over the side of the vessel, and there is also one torpedo gun forward for firing directly ahead. The boiler is of the ordinary torpedo-boat type, constructed for a working pressure of 240 pounds, and the engines are of the direct-acting inverted type, with three cylinders, making 400 revolutions per minute when working at full speed. The coal bunkers are capable of carrying sufficient coal for steaming 1800 miles at eleven knots per hour.

JANUARY 1, 1887. Naval summary of 1886. The defense of London. Military engineering. Improvements in ship ventilation, by Mr. Robert Boyle.

The German journal, *St. Hubertus*, gives a description of experiments made by the 3d Battalion of Jäger at Lübben in the training of dogs for war. The dogs are for the most part shepherd's dogs. Each company possesses two dogs. They are trained to run between the advanced posts and the main body of the battalion, and *vice versa*.

The Impérieuse has been deprived of her heavy and cumbrous masts and spars, as the result of her experimental trial at sea. This change, besides raising her armor belt and torpedo ports higher out of water, will probably enable her to realize the seventeen-knot speed for which she was designed.

JANUARY 8. "Our Navy—The Official View. Remarks by Lord Charles Beresford." Admiral Sir Thomas Symonds' view of the Navy.

A Fleet circular gives notice that vessels proceeding to or employed on the following stations—viz.: China, East Indies, and West Coast of Africa—are to be painted white. The cruiser Archer made a four hours' full-speed trial at Devonport recently. The results were: Draught of water forward, twelve feet three inches; aft, fourteen feet seven inches; revolutions of engine, 133; pressure of steam in cylinders, high, forty-one pounds; low, 13.7 pounds; vacuum in condensers, 25.5 inches; indicated horse power, high, 1032; low, 1187; total, 2219, being over the contract. Speed of ship by patent log, 15.52 knots. This trial was very satisfactory. The Archer is built of steel, is 225 feet long, thirty-six feet beam, and has a displacement of 1630 tons. She has twin screws.

The Cossack, a steel cruiser of the same class as the Archer, was taken outside Plymouth Breakwater on Saturday, January 1, 1887, for trials of machinery and speed under forced draught. The draught of water forward was 12 feet 6 inches; aft, 14 feet 7 inches; pressure of steam in boilers, 118 pounds. Starboard engine—Pressure of steam in cylinders, high, 60.5 pounds; low, 20.6 pounds; vacuum in condenser, 24 inches; revolutions of engines, 155; indicated horse power, high, 894; low, 1045; total starboard engine, 1939. Port engine—Pressure of steam in cylinders, high, 61.0 pounds; low, 21.8 pounds; vacuum in condensers, 26 inches; revolutions of engines, 158.5; indicated horse power, high, 922; low, 1130; total port engines, 2052; total power of both engines, 3991; speed of ship by patent log, 17.8 knots. This was the result of the first two hours. At the end of the third hour some of the boiler tubes became leaky and the trial was discontinued.

On Monday, January 3, the Brisk, a steel cruiser of the same class as the Archer and Cossack, was taken outside the breakwater, Plymouth, for a four hours' full-speed trial under natural draught. Ballast was placed on board to bring the vessel's draught down to seagoing trim, which was 12 feet 6 inches forward, 14 feet 7 inches aft. The steam in the boilers was 116 pounds. Starboard engine—Pressure of steam in cylinders, high, 45.1 pounds; low, 16.0 pounds; vacuum in condensers, 24 inches; revolutions of engines, 137.8; indicated horse power, high, 593; low, 721; total, 1314. Port engines—Pressure of steam in cylinders, high, 45.2 pounds; low, 15.8 pounds; vacuum in cylinder, 24.3 inches; revolutions of engines, 137.2; indicated horse power, high, 592; low, 711; total, 1303; total both engines, 2617; speed of ship by patent log, 15.75 knots. The result was considered highly satisfactory.

On Tuesday, January 4, 1887, the Thames, a vessel similar to the Naniwa-kan, was taken outside Plymouth Breakwater for a preliminary trial of her machinery. The vessel is 300 feet long between perpendiculars, with moulded breadth of 46 feet. At the time of this trial her draught was—Forward, 13 feet 5 inches; aft, 17 feet 3 inches. A short trial was made to test her speed and power under

natural draught. The following was the result: Steam in boilers, 90 pounds. Starboard engine—Pressure of steam in cylinders, high, 45.2 pounds; low, 17.2 pounds; vacuum in condensers, 24.5 inches; revolution of engines, 108.2; indicated horse power, high, 1027; low, 1139; total starboard engine, 2166. Port engine—Pressure of steam in cylinders, high, 51.0 pounds; low, 17.3 pounds; vacuum in condensers, 24.5 inches; revolutions of engines, 110.3; indicated horse power, high, 1181; low, 1148; total for port engine, 2329; making a total for both engines of 4495, being 695 over the stipulated contract. The speed of the ship was 17 knots. The result was satisfactory.

B. F. T.

# Additional Note for No. 40.

## The Money Value of a Saving in Weight in the Armament of a War Vessel.

Where only about 6 per cent. of a ship's displacement is allotted to her armament the reduction of the weight of the guns becomes very important, and it will be interesting to endeavor to estimate the reduction in the value of a completely equipped ship owing to a saving in the weight of the guns.

In General Information Series, No. 5, of the office of naval intelligence is the translation of a paper by Mr. J. Normand, in which it is shown (p. 163) that in designing a vessel an increase, $k$, in the weight of any given object on board necessitates an increase in the ship's displacement of nearly $5k$ in order to retain the same speed, coal endurance, and other nautical qualities.

If we increase the weight of a gun by one ton we must increase the weight of its carriage by about two-thirds of a ton in order that the latter may stand the increased size of the gun, and the consequent increase in the ship's displacement would be—

$$5 \times 1\tfrac{2}{3} = 8\tfrac{1}{3} \text{ tons.}$$

Unarmored high-power ships, such as the "Baltimore," cost about $300 per ton for hull and engines, and therefore an increase of one ton in the weight of the guns would require an increase in the cost of such ships of $2,500.

If we grant that by employing a greater weight of a weaker material we can make cheap guns as trustworthy and as powerful as those now designed, it does not follow that this would be a real economy when the increased cost of the completed ship is considered.

Our present steel 8-inch guns cost, I believe, about $15,000.

The alloys of iron—cast, malleable, and steel—are often colloquially distinguished by the proportion of carbon in combination* with metallic iron. Thus, the first product from the ore (cast iron) contains generally about four per cent. of carbon; the second (malleable iron) is produced by the removal of most of the carbon; and the third (steel) by recharging the metal with carbon.† Each of these processes refines the metal, and the last product gives to steel its highest comparative value. Another distinction is that the alloy which has no carbon is fibrous, and with carbon is crystalline. The value of each of these alloys of iron depends primarily upon the quality of the ores, and next upon the subsequent manipulation of the metal.

The additional charge of carbon, within limits, increases the tensile strength, elasticity and hardness, and, if proper skill and care are taken in the manufacture, the different grades of steel should have an equal degree of "reliability." If they do not, the fault is that of the manufacturer and not of the material. In like manner the size of the mass of any of these alloys, when properly manufactured, need not affect its reliability;‡ where it does so, it is again the fault of the manufacturer.

Cast iron and steel of all grades become fluid at a much lower temperature than wrought iron, and in proportion to the quantity of carbon which they contain.§ The differences of temperature which these several alloys require in the process of manufacture, require a different treatment for each, and when this treatment is made appropriate to steels of different degrees of carbonization, it will doubtless, under similar conditions, produce metals of equal reliability. Experienced manufacturers understand this, and the "capriciousness" of some steel in the market is probably due to inexperience, ignorance, or neglect. The rigid inspection of the ordnance officers would exclude the use of such improperly made steel.

* Not necessarily in its chemical sense. Some metallurgists believe that the mixture is a combination producing a new metal, but generally steel is considered as having only a mechanical union. Dr. Seeman considers steel as simply a union between carbon and metallic iron, and manganese, silicon, etc., as impurities of the alloy.

† The alloy is usually called "cast iron" if the proportion of carbon exceeds two per cent., and "malleable iron" if it contains less than one-fifth of one per cent. of carbon.

‡ By reliability I do not mean *absolute* strength.

§ Cast iron becomes fluid at a temperature of about 1900 to 2700 degrees Fahr.; steel at 2600 to 3300, and malleable iron, formerly considered as infusible, melts at about 4000 degrees.

The use of the oil bath is to suddenly chill the metal while it is in the condition of high temperature, when its crystallization is in a uniform and minute form; it being claimed that if the mass is allowed to cool slowly, the interior crystallization becomes coarse and irregular. The bath, whether of oil or other fluid, chills the exterior first. The subsequent cooling of the interior, while under the pressure of the cooled exterior shell, brings strains which must be subsequently removed by annealing. The effect of the bath extends as deep into the metal as the change of temperature. It appears to me that a process of manufacture which would prevent any material difference of temperature between the exterior and interior during the process, would secure equal strength and character throughout.

In the construction of guns, it is desirable to have the "tube" or inner cylinder of a metal which, with the other requisites, will best resist the wear and tear of the shot and gases, and hence two kinds of metal are necessary; but if thick masses of steel of the required quality, and homogeneous throughout, can be manufactured, the gun will be stronger if made of two than of any greater number of rings.

Some years since, I witnessed the perforation of a wrought-iron shield (composed of two plates of 7 and 8 inches thickness bolted together) by a shot of 624 pounds from a 12-inch Rodman rifle. At the edges of the shot-hole the welded plates, each of an inch thickness, were torn apart by the blow of the shot, 6 inches back from the hole. In a gun made of many thin hoops, the welding would not make as complete union as the metal itself has, and the strain produced by the shrinking of the hoops upon each other might be detrimental to the strength of the gun; but this opinion I give with some diffidence.

The difference in the cost of manufacturing an equal quality of steel of low or high carbonization is inconsiderable. When prepared for bridge-work the metal is worth about $50 a ton, and $10 more to put it into the finished work. The cost of the completed steel gun is said to exceed $500 a ton. The elastic strength of so-called "mild steel" with one-eighth of one per cent. of carbon is but three-fourths of that of steel with the half of one per cent. of carbon. Hence, guns made of metal of the former description would weigh nearly a third more than those of the same strength made of the latter metal. This lessened weight of each gun of the stronger metal, would enable a ship of war of any given displacement to increase largely her armament.

I enclose a copy of the specifications* of the Harlem Bridge, now in process of construction, of which I was the engineer. It will have two arches of 500 feet span, of mild steel. The specifications for the metal-work were prepared by Mr. Theodore Cooper, the consulting engineer.

In a railway bridge of a certain span, half of the strain is produced by the constant static load—viz.: the weight of the bridge itself. The effect of the sudden entrance of a train at high speed constructively produces an equal strain.

* STEEL.—The steel shall be uniform in character for each specified kind. The finished bars, plates and shapes must be free from cracks on the faces or corners, and have clean, smooth surfaces.

All steel for the arch ribs, girders and tension rods shall have an ultimate strength of 62,000 to 70,000 pounds per square inch, with an elastic limit not less than 32,000 pounds per square inch, and a minimum elongation of 18 per cent. when measured on an original length of 8 inches.

All steel for rivets shall have an ultimate strength per square inch of 56,000 to 64,000 pounds, with a minimum elongation of 25 per cent.

Tests shall be made by samples cut from the finished material after rolling. The samples to be at least 12 inches long and to have a uniform sectional area not less than ½ square inch. All the samples must show uniform fine-grained fractures of a blue steel-gray color, entirely free from fiery lustre or a blackish cast.

Samples cut from finished material for the arch ribs, girders or tension members, tested before or after heating to a low cherry-red, and cooled in water at 82° Fahr., must stand bending to a curve whose inner radius is one and a half times the thickness of the sample without cracking. Samples of rivet steel, before and after being heated to a light yellow heat and quenched in cold water, must stand closing solidly together without sign of fracture. To check the uniformity of the material, the manufacturers of the ingots shall cause to be made from each cast sample bars of ¾ inch round, with a definite and uniform reduction equivalent to reducing a 4-inch ingot to the sample size. They shall mark the same in a manner to identify the final product.

The usual chemical tests shall be furnished in connection with these samples.

No work must be put upon any steel at or near the blue temperature, or between that of boiling water and the ignition of hardwood sawdust.

Any steel straightened or worked cold by use of the hammer or gag press must be afterwards wholly annealed.

The contractor must furnish the use of a testing machine, capable of testing the above samples, at all mills where the iron or steel may be manufactured, free of cost.

All facilities for inspection of the material and workmanship shall be furnished by the contractor. He shall furnish the above samples, prepared, of both the steel and iron, without charge.

The strains to which large guns are subjected are very different in time * and degree, as well as the static weight of the structures which receive them. The explosion of the powder creates an almost instantaneous radial pressure upon the metal surrounding the chamber of a ten-inch gun, of perhaps five or six hundred tons per lineal inch of its powder-chamber length, while the weight of the gun itself is comparatively very small. This differs from the engineer's bridge in the intensity of the strains produced, in the time occupied in their development, and in the capacity of the structure to receive and absorb them.

The cheapness of mild steel and its considerable tensile and elastic strength render it suitable for a bridge structure, but for a gun the elasticity and ductility of the metal to receive the first shock is the primary consideration. Subsequently, and immediately afterward, the tensile strength of the gun metal is called into requisition. For this purpose, therefore, steel of the greatest elasticity is first required, and next of the greatest tensile strength.

Experience has demonstrated that steel of about one-third to the half of one per cent. of carbon, with an elastic limit of not less than 50,000 pounds and ductility of 15 to 20 per cent., made from ores of the best and most suitable quality and manufactured with the greatest care and skill and properly bathed and annealed, is the most suitable metal for the fabrication of large naval guns.

NOTE.—I have now in hand the construction of a bridge of two steel arches of 500 feet span, in which will be used 7000 tons of iron and steel; also the Arcade Railway, on the first section of which (five miles) there will be used 60,000 tons of iron and steel. During the past year I have also prepared plans for a steel pipe of ten feet diameter and two miles long, and on another work for steel pipes of three feet diameter and thirty miles long. For each of these works I have considered that mild steel is the most suitable material. You will therefore perceive that I am not opposed to the use of that quality of metal in its appropriate place.

## DISCUSSION.

THE CHAIRMAN.—It is not my purpose to take up any time in attempting to add to what has already been so ably said by the lecturer on the subject of steel for heavy guns. It is easy to account for the fact that but little discussion is volunteered; for this audience, or at least the naval part of it, is, perhaps,

* The conversion of the powder into gas is said to occupy $\frac{1}{1000}$ part of a second, and the pressure developed 15 to 20 tons per square inch.

already prejudiced in favor of just the grade of steel that Mr. McAlpine has advocated as proper to use. Besides being a very instructive paper, it fortifies the position that ordnance officers have taken in demanding a high grade of steel for guns. It is also a matter for congratulation, especially to those who have hitherto defended steel of high grade, to have this endorsement of their views from such undoubted authority.

I am sure all will join me in the agreeable duty of expressing the thanks of the meeting to the lecturer for the pleasure and instruction that he has afforded us.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

# THE NAVIGATOR'S POSITION INDICATOR.

By Lieutenant H. O. Rittenhouse, U. S. N.

The navigator's position indicator is an instrument designed to indicate the position of a vessel when navigating coasts or inland waters where towers, buoys, lights, beacons, or other marks may be seen and recognized. Briefly, it is an instrument whose principal use is to lay down quickly and accurately one or more lines of bearing.

Even under favorable circumstances, and when there is ample time to take the observations and perform the necessary chart work with due care, the method in general use at present can lay but little claim to accuracy. Compass observations are taken generally to the nearest quarter point only, with more or less interval between observations. These bearings are *corrected*, using again the unit of quarter-point instead of the degree. With these approximate bearings the navigator begins work upon the chart with the pencil and parallel rulers. It is difficult to adjust the ruler accurately to the compass diagram, especially if it is marked to half-points only, and it certainly requires time and usually much skill and experience to prevent the ruler from slipping before the line can be drawn. The entire process in all its details must be repeated for the second line.

By use of the position indicator great accuracy is attained, and the time of taking an observation and plotting the result is reduced to a minimum. It consists of a chart table fitted to revolve in a horizontal plane, and capable of being adjusted so that the meridians of the chart which it carries can be brought into parallelism with the corresponding meridians of the earth's surface. Upon a chart so adjusted the direction between any two indicated points is identical with the true direction between the corresponding actual points which the chart represents, and the chart table is technically said to be *in position*.

A vertical standard and pedestal is secured to the deck in a convenient place for taking observations. This standard carries at its upper extremity a fixed metal circle, or dumb compass, of 16 to 20 inches diameter, graduated to degrees, and fitted with an adjustment to compensate for heeling of the ship when necessary. The chart board pivots over the centre of this circle and is supported by it. The standard is secured to the deck so that the initial point of graduation of the circle is in a fore-and-aft line with the centre of rotation, similar to the position of the lubber's point of a compass.

The chart board, which is rectangular in shape, has a metal plate secured to its under surface adapted in form to the upper surface of the fixed circle, and fitted to rotate over it. An index attached to the board moves over the graduation of the circle, and thereby may be set at any desired point of the graduation by a set screw or clamp. The chart is secured to the board so that its meridians coincide in direction with the index.

The station pointers consist each of two parts: First, the station centre, which is a metal cylinder of sufficient weight to maintain its position on the chart when subject to the usual disturbances of wind and other causes. This cylinder is hollow, and fitted with cross-wires near the under surface, by which means it is accurately placed over any specified object on the chart. Second, fitted to revolve upon the station centre is the *pointer*, which has two arms, one carrying the sight vanes, while the other is a simple straight-edge lined with the intersection of the cross-wires, and corresponding in direction with the line of the sight vanes. This straight-edge is raised just clear of the chart, so as to revolve with ease, and also lie conveniently for drawing lines defined by it. A thin washer raises it more when necessary.

The chart having been placed in position upon the board, the station centres and pointers are adjusted over the objects on the chart upon which the observation is to be taken. The standard compass course, or heading of ship if at anchor, is then observed, and the true course found to a degree by applying the necessary correction. Set the table *in position* by moving the index to the number of degrees indicated by the true course and clamp it. The pointers are then turned upon the designated objects, and the crossing of the straight-edges indicates the ship's position directly. Lines may be drawn by the pencil or not, to suit the pleasure. A series of observations may e taken in rapid succession, and the track of the ship traced almost a continuous line.

Increased accuracy over the ordinary method results from the fact that the ship's head and the necessary corrections are all noted without difficulty in degrees. Moreover, when the sight vanes are ranged on the observed object, the line of bearing is already indicated without additional discrepancy.

Vessels of modern speed manœuvring in bays or estuaries could ill afford to lose the time required to read bearings, manipulate the rulers, and permit the observer to pass to and fro between his chart board and the compass. In critical situations the effect of a tide, or current, or a drift of the vessel from any cause, could be readily detected by the indicator.

Slight modifications of the use of the instrument as above described will suggest themselves to the operator. Thus, to insure the chart board being set *exactly* to the course, it is well to adjust the chart board as above described, and let an assistant (the quartermaster) call out when the vessel is exactly on her course. The observation taken then will give the position with great accuracy.

Still greater refinement (possibly of use) is secured by having two observers, one at each pointer, to observe simultaneously. By this means the error due to travel of ship between observations is eliminated. This error cannot well be eliminated from the method by compass bearing, as that instrument is fitted for use by one observer only at a time.

When from accident or design one (or both) of the station centres should not be over the represented object on the chart at the time of observation, it is apparent that the *direction* of the bearing thus obtained is correct, and it may be easily transferred parallel to itself to its true position. The instrument is well adapted to making rough or running surveys, and the station centres and pointers can be used on an improvised plane table for ordinary surveying purposes on shore, giving results the accuracy of which would be inferior only to refined work.

The fixed graduated circle operates with the standard compass, enabling us to turn the chart table in an opposite direction through the angle which the keel is turned away from the meridian. This suggests the advisability of adjusting the zero point of the graduated circle to correspond with the lubber's point of the standard compass rather than to adjust it in a fore-and-aft line by means independent of the compass. The harmonious adjustment of the two instruments eliminates any error due to displacement of the lubber's point.

The use of the chart table ceases when the vessel is out of sight of sailing-marks. It is then dismounted by lifting it from the fixed circle. The circle, however, retains its uses, and the following modifications and suggestions are advanced as tending to facilitate the work of the navigator and officer of the deck:

A suitable station should be provided on every ship, affording an uninterrupted view of the horizon, where the captain, navigator, pilot, or other person responsible for the conduct of the vessel while under way, may perform his duty to the best advantage. The narrow bridges on our men-of-war, which, on important occasions, are apt to become the disputed territory of no less than three officers, and sometimes half a dozen, are not well designed to meet the requirements above mentioned. An offset from the bridge of six or eight feet square, preferably a little higher than the bridge and communicating with it by steps, would, in many cases, answer the purpose. Just where it should be located on a particular ship, however, is subordinate to the consideration that it should be located *somewhere*. In places of difficult navigation, and in fleet and squadron drills under way, it is a necessity, and on ordinary occasions, both at sea and in port, it would be in constant use for lookout purposes.

The dimensions above stated give sufficient space in which to set up a dumb compass, mount a chart board, and give room to move about and operate them. The design of the position indicator embraces the use of a dumb compass in the following manner:

The dumb compass consists of two discs or circles; the under one, fixed in position, and having its zero mark to indicate the direction of the keel, being the same as previously described as part of the position indicator proper. The upper one revolves over the lower and carries an index and clamp, and is graduated to degrees and to quarter-points. The lower disc is used as a means of setting the upper one to correspond with the course. When the index is set to any course indicated by the graduation of the lower disc, the upper disc becomes practically a *live* compass while the vessel continues on such course, and all bearings noted by the upper disc are ready for application to the chart. When the index is set to the *true* course, the bearings obtained are *true* bearings; when set to the *magnetic* course we have *magnetic* bearings, and when set to the *compass* course we have *compass* bearings.

Over the upper disc are pivoted two alidades with sight vanes, working independently of each other, and permitting two bearings to

be taken simultaneously. Set-screws clamp them at will. It will be observed that the entire work may be carried on by degrees instead of quarter-points, no reduction is applied to the reading, and when the vessel is going swiftly simultaneous observations eliminate the usual error due to interval of time.

By means of the binding-screws the two alidades can be set at any desired angle with each other, as, for instance, in the problem of keeping the vessel outside the danger angle, or in navigating curved channels on the arc of a circle by a single angle, described by Commander H. C. Taylor, U. S. Navy (Proceedings U. S. Naval Institute, No. 37).

In fleet evolutions the two alidades, set at right angles with each other, would give both bow and quarter bearings without changing the adjustment. In simpler formations it would give ahead and astern and beam bearings, and at high speeds would be of great use in determining and preserving bearings and intervals. The use of such dumb compass would substitute a refined and accurate instrument for the rude lines scribed or painted upon the decks and bridges of ships.

In inshore navigation, when it becomes desirable to use the chart on deck, we have simply to unship the alidades, lay the chart board on the upper disc, and secure it by the same central bolt which previously held the alidades. The position indicator is then ready for use, the two pointers taking the place of the discarded alidades, and indicating on the chart the line of bearing as soon as observed.

It will be noticed that nothing whatever in the appliances here suggested interferes in the slightest manner with the use of compass bearings and parallel rulers, when from any cause such method is preferred.

The principle upon which the instrument is based is exceedingly simple, and has been familiar to navigators and surveyors for a long time. It is the basis of "A New Method of Making Running Surveys," described by Ensign J. H. Fillmore, U. S. N., in No. 33, Proceedings U. S. Naval Institute, and an excellent description of it is given by M. Delafon in the *Revue Maritime*, May, 1885.

The application of the principle as hereinbefore described is obviously but a modified form of the surveyor's plane table. This instrument has been highly developed by the officers of the U. S. Coast Survey, and the report of that office for 1880 contains a complete description of the instrument and its uses. Its great capacity for locating positions, the readiness with which it is adapted to the various problems in surveying, and its harmonious combination of

the qualities of convenience, accuracy, and dispatch are the chi reasons for the preference given it over all other instruments for th purpose; and this preference is a most significant proof of the valu of the principle.

As an illustration of the facility with which the instrument can b applied to problems in navigation, it may be mentioned that, inde pendent of the compass, it furnishes a practical solution of the three point problem without measuring the angles or using the protracto Thus: Put the chart-table *in position* as nearly as possible by th eye. Place the station centres and pointers over the three object *A*, *B*, and *C* on the chart, draw bearings to the real objects whic they represent, and denote these lines respectively by *a*, *b*, and *c*. now we use the dividers, the perfect solution is obtained by the inte section of the two circles, one through *A*, *B* and the intersection *a b*; the other through *B*, *C* and the intersection of *b c*.

If, however, we do not wish to work with dividers, but confine ou selves to straight lines, we obtain an approximate practical solutio as follows: After drawing *a*, *b*, and *c* as before, change the adjustme of the board slightly (turn the board in the direction to make a bett adjustment to the meridian if possible) and draw new bearings, $a'$, $b$ and $c'$. $a$ and $b$ meet in a point $K$; $a'$ and $b'$, in a point $K'$. Sim larly, $b$ and $c$ meet in a point $L$, and $b'$ and $c'$, in a point $L'$. Joi $K$ and $K'$, also $L$ and $L'$. The intersection of these two lines is th practical determination of the observer's position. [Many othe methods can be used; for which see U. S. Coast Survey Repor 1880.]

Its success in practice depends, of course, upon the good qualiti and careful adjustment of the compass with which it is used; an even if the compass corrections are not accurately known, the ind cator can give *no worse* results than the ordinary compass metho The ship's compass of the present time is so much improved, an with ordinary attention bestowed upon it, is so reliable an instrumen that no objection to the use of the position indicator could arise fro such consideration. I enjoyed the opportunity last summer, on th U. S. S. Jamestown, of experimenting with the instrument in a modifie form, such as could be conveniently made on shipboard, and th result of these experiments fully justified my expectations. The u of accurately constructed instruments utilizing this principle, whereb the ease, rapidity, and accuracy of ordinary chart work are greatly i used, would fully supplement the efficiency of our compasses.

S. NAVAL ACADEMY, *January* 1, 1887.

The accompanying diagrams show the principal features of the instrument:

FIG. 1.—Perspective of the chart table when in use.

*B*, fixed circle secured to upper extremity of the standard.

*b*, index } attached to chart table.<br>*H*, clamp wheel }

*e f*, *e*, *e*, etc., permanent lines drawn on upper surface of chart table for convenience in securing the chart in proper position. [A meridian (or parallel) of the chart is continued over the border and made to coincide with one of the lines.]

*L*, *L'*, station centres upon which revolve the pointers.

*MQ* and *M' Q'*, pointers indicating the position of the observer at *S*, where the right-hand edges of the pointers intersect.

FIG. 2.—*MNOPQ*, pointer shown in position over station centre.

FIG. 3.—Section of same.

*g*, thin washer for raising the straight-edge *MN* when necessary, that it may move freely over the second edge *M'N'*.

# U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

MARCH 4, 1887.

COMMANDER W. T. SAMPSON, U. S. N., in the Chair.

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# PRESSURE-RECORDING INSTRUMENTS.

BY JARVIS B. EDSON, M. E., OF N. Y.

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*Mr. Chairman and Gentlemen:*—The brief time I shall ask your attention this evening precludes the possibility of my devoting any attention to all of the various instruments and appliances for indicating and recording fluid pressure. I shall therefore limit myself to the consideration of that class of instruments which have been brought forth as reliable, and applicable to pressures varying from an absolute zero to that of a few thousand pounds per square inch (*they* forming those of the most extended manufacture and use in the daily arts), and conclude with a few words on their application and desirability.

Instruments for only indicating pressure have been made under two general types—that of the bent tube, after Bourdon, and that of the vibrating diaphragm, from the German. These move according to the fluctuating pressure applied, and such movement I term "original travel." The pressure upon them is determined by the mercury column as a standard, and their scales and dials are laid off accordingly. Starting with the assumption that the mercury column is accurately constructed and properly used, we have to consider the form and appropriateness of the metals employed in these two types for sustaining without change or "set" constantly varying strains and shapes so that similar exposure to pressure shall result in similar travel and dial-reading. The two types mentioned have, as a rule, predominated for indicating purposes in about equal numbers, and been accepted as equally trustworthy and reliable by the masses, who neglect to question or probe beneath the surface. When we consider that the

duty is that of a spring, based upon the resilience of the metal composing the same, it seems somewhat strange that the Bourdon tube, made of brass composition, should even be expected to act equally with the properly tempered disks of steel. Ordinarily, where the vicissitudes of its use admit of the same, we invariably employ tempered steel when we want a spring, as we know more about making it of that metal than we do of alloys of copper, tin, etc.; and in practice the failure in the Bourdon tube is due to the yielding of the metal composing it, while the steel diaphragm, when well made, has an endurance which nothing but tempered steel can give. Unfortunately, however, these diaphragm instruments have been poorly made both as to the spring and the multiplying mechanism for throwing the hand around the dial. Nor does the most difficult portion of the problem consist in simply providing a reliable spring, because it is equally important to have a uniform and lively "travel" from the pressure itself, in order to dispense to the utmost degree with the introduction of multiplying gears, which multiply errors as readily as they do the "original travel." Of equal importance is it, also, that the *persistence* of the "travel" shall be able to overcome the friction to be encountered in moving the multiplying and indicating mechanism. This persistency of change, due to the variable pressure in the *tube*, is extremely slight, and in the *diaphragm* very great. In the latter it is determined by multiplying the exposed area of the diaphragm by the pressure in pounds per square inch it is sustaining. As friction must be overcome and work done without disturbing the accuracy of the instrument in its movement, this "persistency of travel" possessed by the diaphragm alone is a very important feature. Therefore it is sufficient for our present purposes that we take into account only the consideration of steel diaphragms and their superincumbent mechanism for giving multiplied travel to the hand upon the dial.

By custom, for commercial purposes, they have been made of French and English steel, varying in thickness according to the pressure to be sustained, and cut into small disks two and one-half inches in diameter, and corrugated slightly to increase their displacement under various pressures. Such disks give a travel of only one thirty-second of an inch. No reason is to be found why this small diameter was selected, or why it has always been adhered to. The total "original travel" from the pressure itself must be proportionate to the diameter, and while a greater travel is always ultimately required for dial purposes, it has only been obtained through high multiplica-

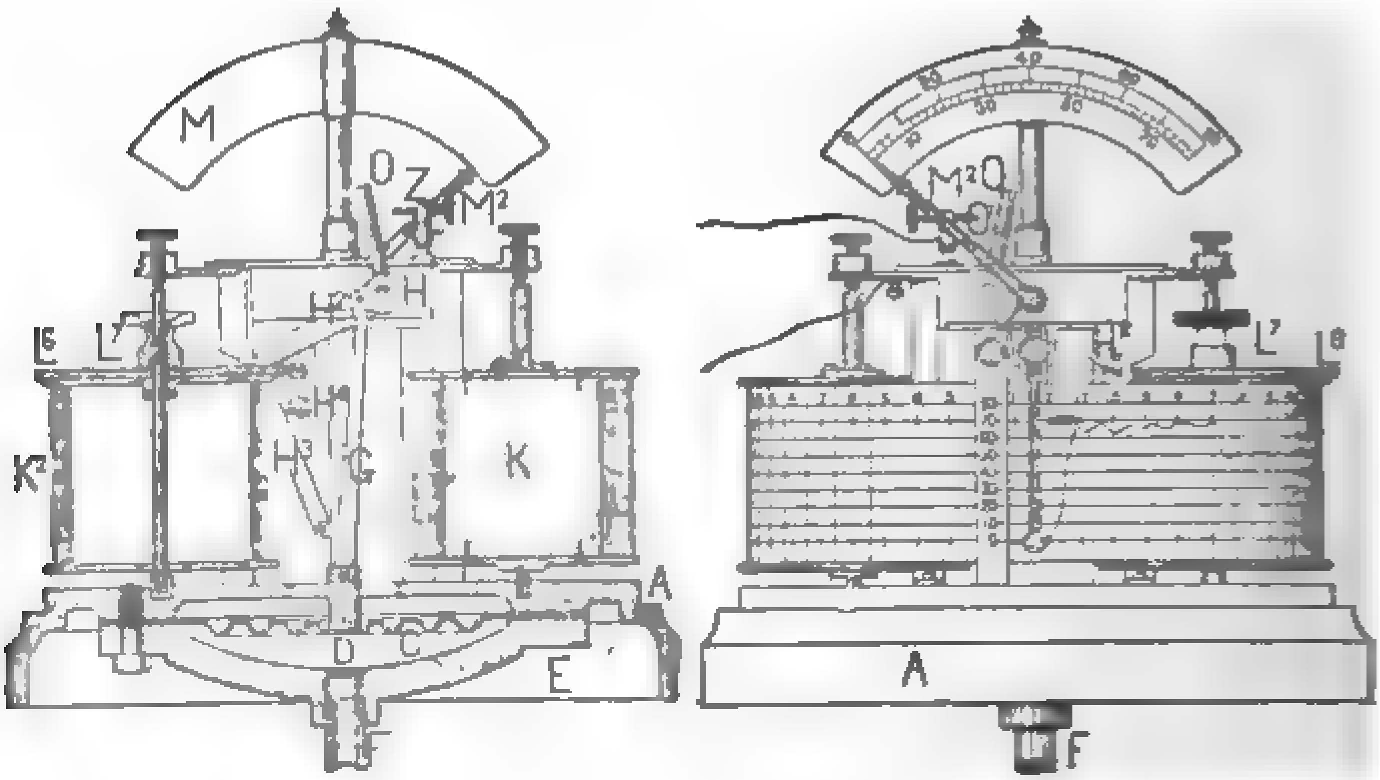
tion, by gearing of the small "original travel," and at the expense of durability and accuracy.

My attention was called to this matter in 1869 or 1870, and soon discovering that the diaphragms in use were improperly constructed, I at once introduced two improvements, which consisted in corrugating the diaphragms convexly, and increasing the dimensions and amplitude of such corrugations from the centre to the circumference. This resulted in more than doubling the "original travel" previously obtainable from a given diameter and thickness of disk under similar pressure. Thus encouraged, I increased the diameter from two and one-half to six and one-half inches, obtaining an "original travel" directly from the pressure itself, without multiplication, of from three-eighths to one-half an inch. With an abundance of travel, I also had a "persistency of travel," unaffected by any reasonable amount of friction to be encountered in moving an indicating or a recording mechanism. In fact, at this point started the present recording apparatus, after the continuous failure of many others, here and abroad, in their attempt to get a competent and durable source of "original travel" suitable for a pressure-measuring and recording mechanism. That the problem then received no meagre solution is attested by the fact that the type of pressure recorder here exhibited has been in extensive use since 1875.* On the other hand, while the pressure-recording instrument has been steadily making a record of reliability for itself, the simple indicating gauge has as steadily pursued a retrograde course, until now the commercial instrument is so carelessly standardized, if standardized at all, that reliance upon it becomes positively dangerous, and cannot be too strongly deprecated. In fact, the eminent engineer, the late J. C. Hoadley, as one of a committee appointed to compile a code of rules to be adopted in making steam-boiler tests, specifies an Edson recording gauge and its record as a good check upon the indications of the ordinary steam gauge. So in the report for August, 1885, of the inspectors of the Hartford

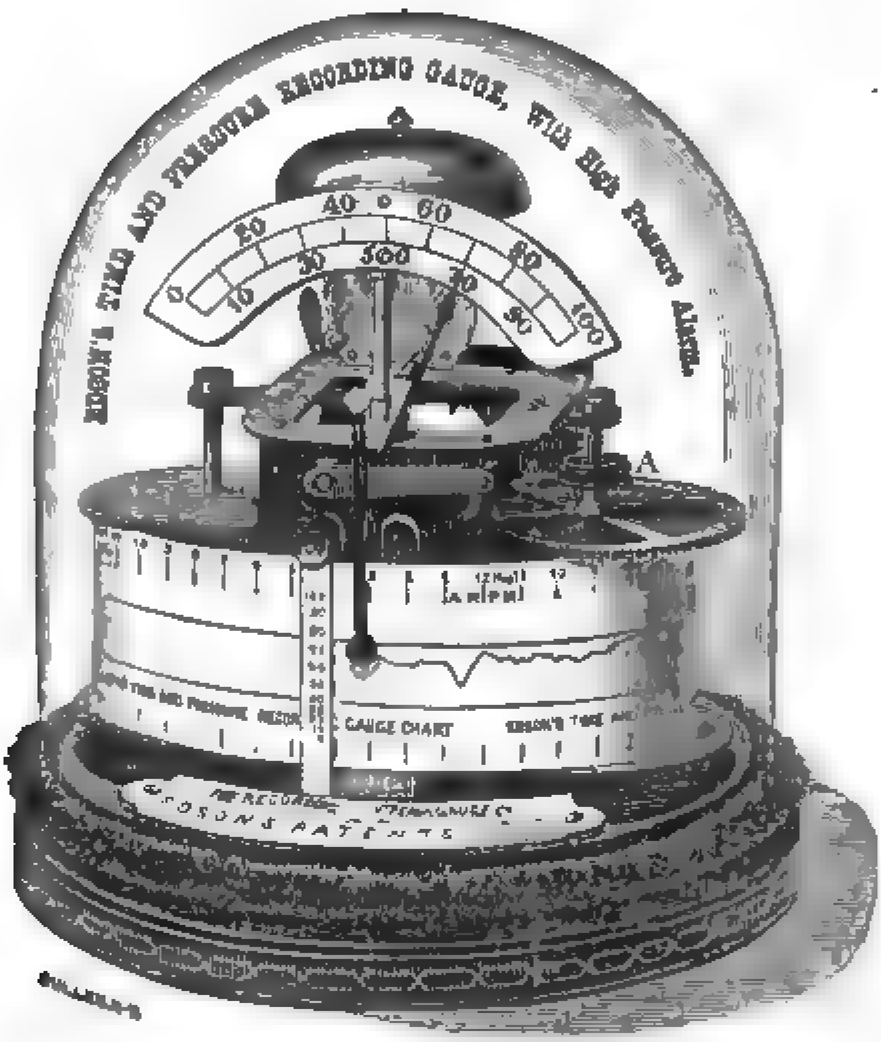
* These instruments were accepted by the Government authorities as being in full compliance with the law of Congress requiring steamers to carry pressure-recording gauges; were used by the special board of experts in their extensive and crucial boiler tests at the Centennial Exhibition in 1876, and met the approval of the special expert in charge; were ordered to be used in the United States Navy, after trial and test by the Engineering Department; were adopted by the British Admiralty in large numbers, and by the Government buildings in Washington and many other cities; also on transatlantic steamships, etc.

Steam Boiler Insurance Company, they give: 255 pressure-indicating gauges defective—31 dangerously so—and 2 boilers *without* them; report for April of same year gives 169 defective, 42 dangerously so.

The instrument referred to, briefly described, consists of a metal base $A$, enclosing beneath it a tempered diaphragm $C$, so arranged that when the fluid enters the space $D$ between the spring and the cap $E$, forming the chamber, the spring is deflected upwardly. The recording apparatus is mounted on the top of the base $A$, and the movement of this diaphragm $C$ is transmitted through the arms $H_2$ and $H_3$ on the rock shaft $H$, by means of the connecting bar $G$, to the vertical moving pencil carrier in front, thrown thereby about six




times the original travel of the diaphragm. Simultaneously therewith, motion from the same rock shaft $H$ moves the hand $M_2$ before the dial $M$. A special clock mechanism revolves the receiving reel $K_2$, contributing the element of time to the chart drawn from the reservoir reel $K$ on the left, beneath the recording pencil. Ordinarily this reservoir reel $K$ contains a supply of charts for thirty days. A glass dome surmounting the whole enables inspection and excludes dust, moisture, etc. The supplemental, adjustable arm $O$ upon the rock shaft $H$ acts both as a circuit closer for an electro-magnetic alarm, and operates a mechanical alarm usually provided with each instrument.




This form has been found successful in recording pressure from two pounds per square inch for blast furnaces, to (1200) twelve hundred pounds per square inch used in pumping oil. For recording temperatures of drying-rooms, etc., a supplemental diaphragm is employed to increase the travel, owing to the low coefficient of expansion possessed by the fluids used for the various temperature ranges.

I take it that, of all the various uses to which pressure-recording instruments are put, none equals in importance, practically, that of being called upon to stand sentinel over the pressure of steam. Certainly no other explosive element is encountered so frequently, or enters so largely into our domestic economy; and equally true is it that no other is produced in such ignorance or left to such carelessness. Attendant safety and economy are almost entirely left to become matters of chance, and while the average steam user readily accords due homage to a pound of gunpowder known to be stored about his establishment, willingly assuming it to be dry, he cannot be made to believe that each cubic foot of water in his boiler under sixty pounds of steam contains the explosive energy of that same pound of gunpowder. Equally true is it from an economical point of view that

the stoker who will labor the cheapest is the cheapest laborer to his mind; and while ready to denounce as extortion a demand for an increase of wages of even five per cent. on the part of the boiler attendant, he readily pays, unquestioned, any coal bill at sight, though its excess may more than equal the wages of the man.

A well-constructed boiler, proper firing, moderate draught and steady feed—these form the basis of the best economy. The pressure of steam in the boiler will vary from two causes—upwardly from excess of supply over demand, and downwardly from the demand exceeding the supply. Now, if the demand be constant, there is no reason why the supply should not be constant also. If, on the other hand, the demand for steam is variable, does it follow that the supply should also become inconstant? Inequality in *demand* may be regular and right, but inequality in *supply* is never right, for the conditions which give rise to it are almost invariably attributable to carelessness or ignorance or inexperience. This is, to a large extent, the natural consequence of the peculiar conditions under which steam is generated. The idea prevails that, to obtain steam, *coal must be burned*, and in order to practise frugality the *cheapest labor* must handle it in the fire-room; while by the same intelligence the conclusion is reached that the *engine* must be presided over, for *economy's* sake, by a skillful and experienced man—of necessity! But we are not all ignorant of the relative stewardship of the boiler with the coal supplied it, and the engine with the steam it gets; and the time may not be far distant when, copying the practice from the Caspian Sea and substituting oil for coal, we may not only better *use* our fuel, but bring mechanical appliances in play which will be much more reliable than careless or ignorant human agents can be. The most ordinary intellect would at once intuitively, as it were, recognize the necessity for supplying the stream of oil in just the proper quantity uninterruptedly, and would strive to preserve the proper adjustments of the apparatus for its accomplishment; while the same person, if using coal as a fuel, would entirely ignore the extra necessity for vigilance and attention required to maintain a steady supply of it, and a uniform rate of its distillation into the gases of combustion. That from five to thirty per cent. of the fuel used for a given steam production can be saved or wasted, never occurs to the average fireman or his employer; and, therefore, the fidelity to duty imposed upon him by the knowledge of the operation of the pressure-recording gauge compels him to give the utmost attention to his work, and so, incidentally, to practise economy.

Once, during a three years' cruise in the "service," just after the close of the war, I took the trouble to compare the amounts of coal burned by the different watches for a continuous period of ninety days' steaming. There were three watches of firemen and four of engineers. Taking the coal consumed per knot by the most economical officer as a standard of comparison with the others, the results gave a difference, respectively, of eight, twenty-two and thirty-odd per cent. That is, thirty per cent. more coal was consumed per knot made when one engineer was on duty than was consumed with another.

I mention the matter not as a specimen of poor engineering, but for the purpose of showing it to be possible to get rid of an excess of thirty per cent. of coal without generating the heat and steam due to its consumption. Seldom does it occur to the proprietor that his steam boiler has a direct passage from the furnace door to the smoke stack, through which the heat from the furnace may pass and become fugitive without his having properly arrested its motion, or taken from it that to which he is entitled. Nor does he realize or know how little of the theoretical value of the coal it is possible for him to obtain under the best of conditions and with the most modern pattern of boiler skilfully fired. Ignorant of how little he could get under such circumstances, he little realizes how much he loses under the average practice. Still he continues to look for cheaper labor, and does not complain of larger coal bills.

The extravagant use of fuel is but *one* of the sources of loss occasioned by carelessness and ignorance, to be remedied, to a great extent, by the simple adoption of that form of pressure gauge that shall make a time record of its indications. That unobserved loss which comes gradually but with unerring certainty in the form of the impairment of the boiler's condition is, perhaps, of paramount importance to mere loss of fuel. One affects financial results solely, and the other deals directly with safety of life and property as well. Therefore, whatever unnecessarily injures or weakens a boiler should be avoided voluntarily, or, by legal enactment, prevented, as no one has the right to hazard either life or property; and the employment, wherever fluids are maintained under great compression, of an instrument which shall record upon paper what that compression is and has been, is not only scientifically expedient and useful, but becomes a manifest duty towards those who are in any way endangered thereby.

Since the discovery of the value of steam for a motive power, and for various other uses rendering steam boilers a necessity, no means

have heretofore been produced by which reliable records of the pressure to which such boilers were from time to time subjected could be obtained automatically, and to the very absence of which, in a great measure, are to be attributed the constantly recurring boiler explosions, with the usual verdict of "nobody to blame" when investigations are held. Without these records of the pressure carried, the fireman, who is frequently left in charge night as well as day, may take as much risk in carrying steam as suits his convenience or ignorance, regardless of economy and safety, and without fear of discovery. Before closing I wish to show you some stereopticon views, and the accompanying records of boiler pressure carried in the places severally named, and automatically written by means of Edson's time and pressure-recording steam gauges, are half-size reproductions from the originals.

Chart No. 40 is from the steamship Germanic, White Star Line. The fluctuations shown are attributable to the delays incidental to a steamer entering the port of New York.

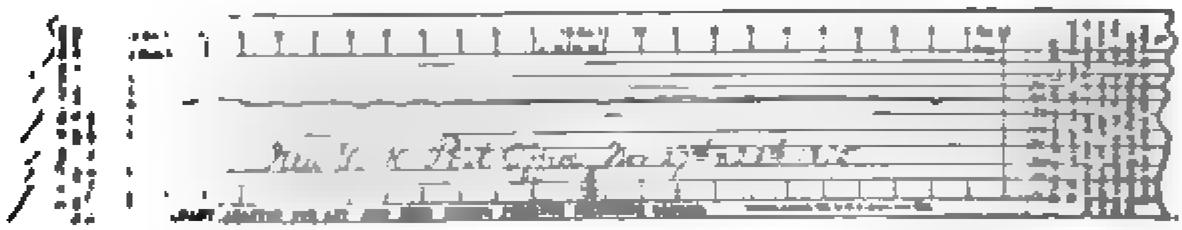


Chart No. [illegible], from the New York Post-Office, is a fair specimen of the regular manner in which steam can be maintained, notwithstanding the varied demands, [illegible], made upon it.

[illegible] shows how a night fireman who was paid for keeping steam at [illegible] succeeded, and unwarrantably strained the boiler twice [illegible] A. M. to the extent of over 25 pounds above the point at which the [illegible] valve was supposed to have been set. This record led to the dis-

covery that the said safety valve had been overloaded to 80 pounds unknown to the Superintendent of Public Buildings, in whose charge the boilers were placed. These facts might never have been discovered and a disaster might have occurred, requiring experts and juries to solve the problem of a boiler bursting from over-pressure, with the so-called safety valve set at 40 pounds, while in fact the boiler sustained a suddenly accumulated pressure of over 60 pounds, as shown by the chart.


Chart No. 53 is from the Chelsea Paper Mill. The circumstances and conditions under which it was taken are not now known. It is reasonable to suppose, however, that with such extreme and sudden fluctuations of pressure, and of accompanying temperatures, the manipulation of materials used in the making of paper is very much affected, and the resulting products unsatisfactory. The boiler also, however well made, cannot long withstand the violence to which it is, in such a case, manifestly subjected.

Several of these charts show that steam can be, and is, carried, not only for hours, but days, with a nearly uniform strain upon the boiler; and where (as on ocean steamers) uniform speed is required and attained, other charts demonstrate clearly that ignorance, recklessness, or want of *thorough supervision*, renders the use of that valuable element uncertain in its results, and the generation thereof, in charge of improper persons, dangerous in practice.

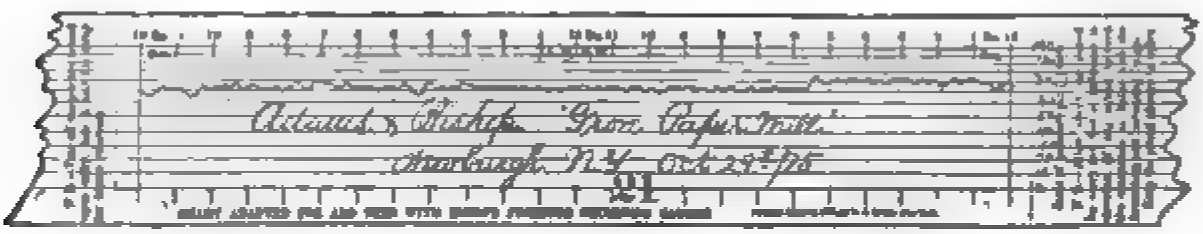



Chart No. 21 was taken in one of the paper mills of Messrs. Adams & Bishop. Mr. Adams is, perhaps, the oldest paper maker in this country. He has two of these recording gauges at work, and requires the charts to be sent from his mills in the country to his office in New York, daily, for his inspection.

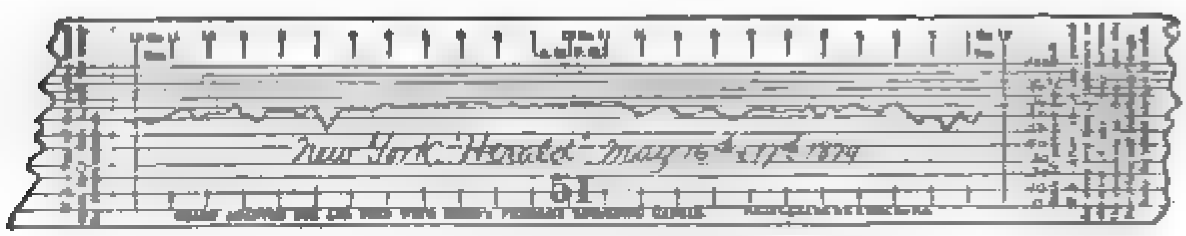



Chart No. 51 is from the New York *Herald*. Its former distinguished proprietor, the late James Gordon Bennett, was among the first to discern the

merits of this invention, and to apply it to practical use in his establishment. It enabled him, or his superintendent, to view at a glance the work performed in the engineer's department; and when disputes arose between the foreman of the press-room and the engineer, the charts were appealed to, and the engineer was generally triumphantly vindicated. The tracings shown demonstrate clearly that between 10.30 P. M. and 6.30 A. M. (while the morning edition was being printed) the pressure of the steam was kept very nearly at 70 pounds. The undulations in the lines during the other parts of the day were doubtless in consequence of the variety of work performed, as hoisting of material, etc., by elevators, occasional printing, and the application of steam for heating and other purposes.

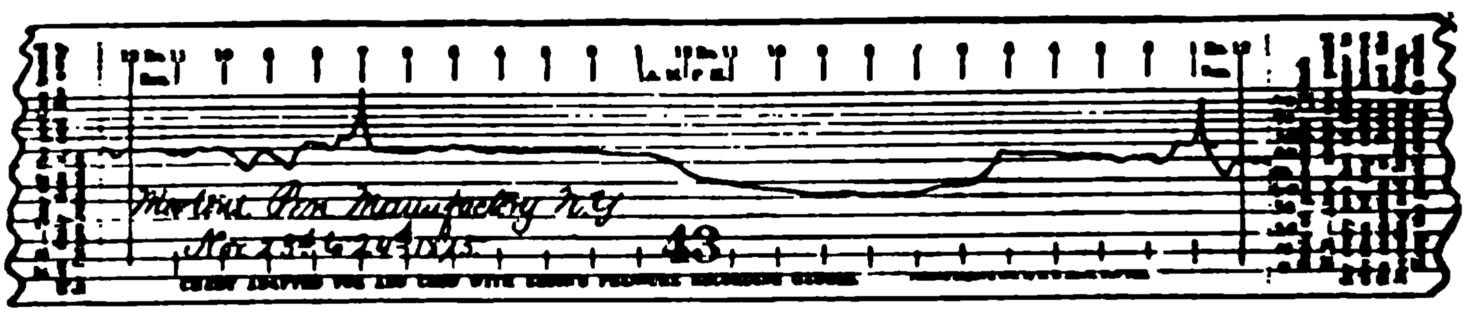



Chart No. 43, from Morton's pen manufactory, New York, illustrates the delusion that thousands who use steam are under, when they assert that *they* "never carry steam at night," and that they "have a careful and competent fireman or (engineer), who economizes fuel," etc., etc. The chart shows that steam commenced falling at 5.15 P. M. At 6 P. M. the fires were banked for the night, there being no further use for steam until 7.30 the next morning; yet, from some unknown cause, the steam gradually accumulated after 9.30 P. M., and at 1 A. M. it had reached 66 pounds; from this time it remained at about the same pressure until 6.45 A. M., when the engineer came, cleaned his fire, and ran steam up to over 120 pounds by 7 o'clock, as shown by the chart. Comment upon so unnecessarily straining a boiler is not required.

The late eminent Chief of the Bureau of Steam Engineering, W. W. W. Wood, wrote as follows, in November, 1870: "I attach great importance to your recording gauges, by which *extravagance in use of fuel may be positively detected*, and accidents, which too frequently involve the loss of life and property, may be avoided." It hardly seems as though an intelligent man could say otherwise; but still they do exist.

In conclusion, does it not seem that our age is too far advanced in scientific improvements longer to permit boiler explosions and consequent loss of human life through negligence, ignorance and sordid notions of economy? I am warranted, by the indisputable records of charts for years, in saying that the Edson pressure-recording gauge writes a constant and unimpeachable record of the facts of variations of fluid pressure, and without which no steam boiler "plant" can be conducted either intelligently, economically, or safely;

that there is no longer excuse for mistakes or ignorance resulting in loss of life or property either on land or water, for, by the use of this pressure-recording gauge, the utmost immunity from danger, greatest economy in fuel, and the fullest information are obtainable. Surely such instruments are not only cheap in the end, but, where lives are in jeopardy, they are imperative and of moral obligation.

## DISCUSSION.

Passed-Assistant Engineer W. F. WORTHINGTON, U. S. N.—*Mr. Chairman and Gentlemen:*—No one who has had charge of a marine engine will deny that a record of its performance is of great value. The first thing an engineer wants to know when coming on watch is how the machinery has been working, not only with regard to cool journals and smoothness of movement, but every detail of pressure, speed, amount of coal, etc., in order to know what requires his first care, and what his principal duty will be for the next four hours. If the record of the log as now kept—with only approximate accuracy—is of real value, it is evident that greater accuracy would increase its value. As long as the officer on watch can remain on the engine-room platform, and the steam pressure does not vary much, he can judge pretty well the average pressure for the hour; but let his attention be diverted for fifteen or twenty minutes, or longer, by a hot journal or a refractory feed pump, and the record of steam for that hour will not be worth much for scientific purposes. If the revolutions which are recorded automatically are the same, and also the vacuum, etc., he will probably assume that the average steam pressure was also the same; but this is at best a guess, and might be a wrong one, owing to a change in the direction or force of the wind which would allow the same number of revolutions to be made with less pressure. One of the most important uses of the recording gauge is to correct the error of observation due to the observer. I believe this error to be as much as two or three pounds. If this is cumulative—that is, if several observers come on watch in succession, each with a tendency to mark the pressure a little higher than it is—the steam may have been going down very gradually from neglected fires or change in quality of coal without the fact becoming apparent, until finally the speed of the ship is materially affected, and several hours are required to bring things back to their proper condition. The general tendency of the pressure, whether up or down, cannot be observed in so short a time as four hours. At the end of that time another observer comes on duty, and it is not known whether he records too high or too low, so that eight hours pass without affording a clue to the desired information; and this is sufficient time for the fires to get dirty if the coal is bad, or for the water-tender to run the water too high in all the boilers, so as to have time for a quiet smoke on the morning watch.

One of the first results of the introduction of recording gauges on shipboard would be more uniform firing, with all the well-known advantages to be derived therefrom. A diagram, such as is drawn by the Edson gauge, appeals

to the intelligence of the most untutored fireman, and there would be a friendly rivalry between the different watches to produce the best results, just as there now is to get the greatest number of revolutions recorded by the counter. Another advantage would be, that if one watch were weaker than another, the fact would become apparent by examining the diagrams for several days, and the men could then be rearranged to produce more even firing. Of course this can be done now, but not so well, owing to the doubt of the accuracy of the steam pressures recorded by different observers. Another advantage would be the greater accuracy in determining the mean I. H. P. for the day.

Up to the present time there is no reliable continuous steam-engine indicator, and it is necessary to average the steam pressure for twenty-four hours and then get an indicator diagram with the steam pressure, cut-off, etc., the same as the average shown on the log for the twenty-four hours. If the pressures recorded for each hour are not exact to several pounds, it may easily happen that the errors do not balance, but all lie on one side of the truth, and the mean I. H. P. would be deceptive.

Every one who has attempted to draw conclusions from the data recorded in the steam log, has felt the inconvenience which arises from the uncertainty with regard to the steam pressure. The vacuum, the revolutions, temperature of the feed, weight of coal, etc., can be ascertained with considerable accuracy or within fixed and comparatively narrow limits; but the steam fluctuates widely—as much as ten pounds when the working pressure is sixty—and therefore the conclusions drawn can only be relied upon as correct within these wide limits. It has frequently been observed that duplicate engines, the same in every detail, apparently, produce different I. H. P. A recording gauge, applied to each in turn, would soon determine if this difference was real, and thus advance us one good step towards the solution of an interesting and important problem. The engines of warships should be of the highest attainable efficiency, and, in order to make them so, it is necessary to know their defects. The best and, indeed, only way to discover these defects is to get accurate data of the working under every circumstance, especially at sea; and the way to get this data is to have it recorded automatically, because no one can devote his whole time to watching the various instruments. The only objection I ever heard to the use of a recording gauge was that it was unnecessary, because the officer on watch was trustworthy and it would not be right to set a machine to watch him. A complete answer to this objection is that one who does his work well does not care who knows it. One in charge of an engine has many other important duties besides watching the steam gauge, and the recording and alarm apparatus would materially assist him. The attachment for recording the number of revolutions simultaneously with the pressure is a valuable addition to the Edson gauge. The pressure and revolutions often vary independently of each other, and when the latter vary—a fact at once detected by a practical ear before any of the other instruments note it—then the cause could immediately be inquired into and the remedy applied. Although, in time of peace, every run made by a war vessel should be a trial trip in one sense, the value of the recording gauge would appear highest when a full-power trial is made. On such occasions the danger of hot journals, breakages, etc., is greatest, and every one on duty is

fully occupied in causing the machinery to do its utmost, so that just when there is most need of getting correct data there is least time to collect it.

Lieutenant A. M. KNIGHT, U. S. N.—*Mr. Chairman and Gentlemen:*—I have been requested, in connection with the subject of the evening, to give a description of the pressure-recording instruments used in the experimental firing of great guns.

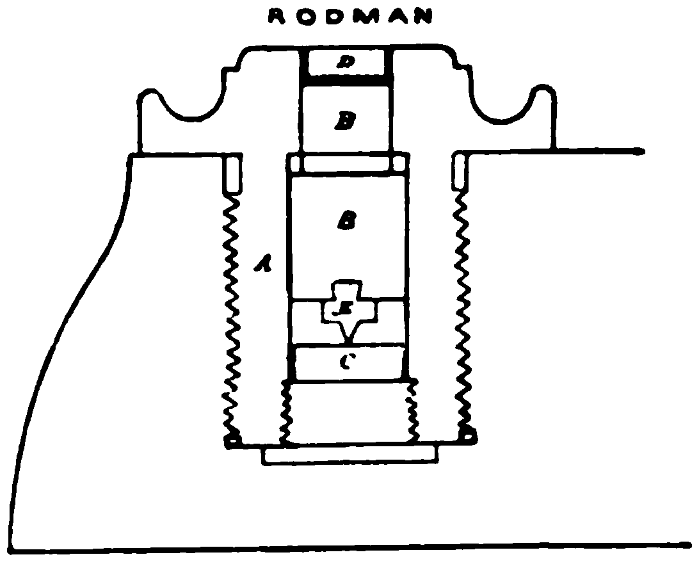
The difficulty in measuring the pressure developed by a powder charge burning in the bore of a gun arises from: 1st. The magnitude of the pressure involved; 2d. The suddenness with which it is developed; 3d. The brevity of the time through which it acts; 4th. The rapidity with which it varies during that time, under the influence of conditions of temperature, motion, etc., of which we have but a very limited knowledge.

The magnitude of the pressure involved, which commonly varies from twelve to twenty tons to the square inch, and in exceptional cases rises to twenty-five and even thirty tons, would of itself put out of the question the employment of any ordinary gauge. Various instruments have been invented which meet this and the other sources of difficulty enumerated above with more or less success. Of these, those which are in practical use at the present time may be divided into two general classes: 1st. Those in which the pressure is measured by opposing to it a known high resistance—usually the resistance of a ductile metal like lead or copper to deformation by cutting or crushing—and 2d. Those in which the pressure is measured by its effect in imparting velocity to a body of known dimensions and mass.

Of the first class, the most important examples are the Rodman, the Woodbridge and the crusher gauges, and the Deprez manometric balance. To the second class belong the Noble chronoscope, the Sébert velocimetre and the Sébert self-registering projectile.

The Rodman gauge (Fig. 1) was invented about 1857 by Colonel Rodman, of the United States Army, and embodies the general principles of the more recent Woodbridge and crusher gauges.

RODMAN



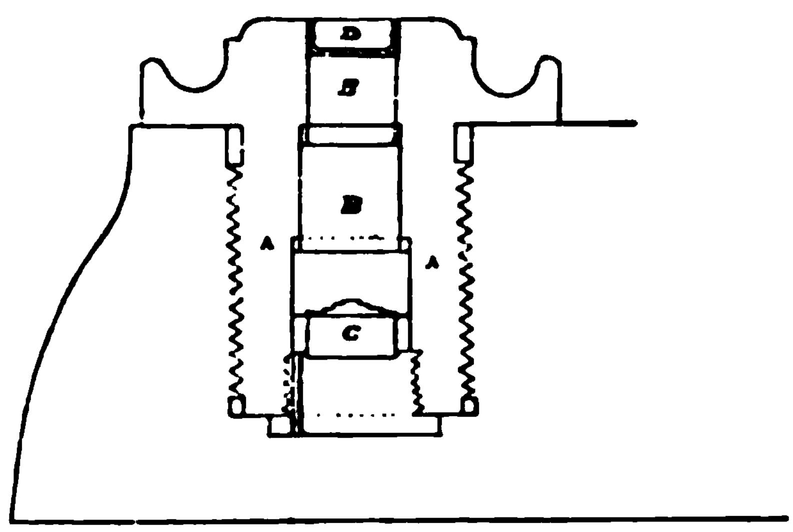

It consists of a steel cylinder, $A$, which screws into the wall of the gun or into a plug inserted in the powder chamber, its head being flush, or nearly flush, with the surface of the bore. Within the cylinder is fitted a piston, $B$, one end of which, when the gauge is in place, is just inside the head of the

gauge and free to be acted upon by the gases developed in the bore on firing. To the other end of the piston is attached a knife-edge, *E*, of tempered steel, and in light contact with this is placed a disc of copper, *C*, resting upon the screw plug which closes the base of the cylinder.

A copper cup, *D*, placed over the head of the piston, acts as a check to prevent the gases from entering the gauge.

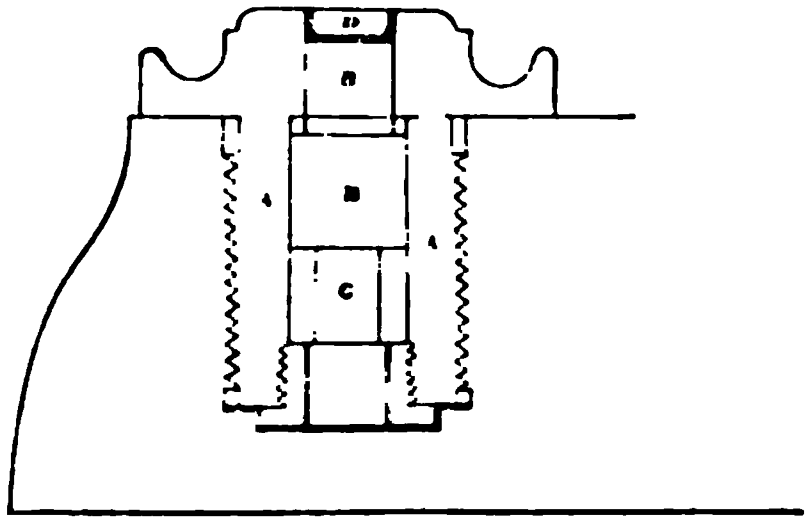
When a pressure is developed in the bore of the gun, the piston of the gauge is forced inward, and the knife-edge enters the copper disc to a depth dependent upon the amount of the pressure. The gauge is then removed from the gun, the disc taken out, and the dimensions of the cut measured and compared with those of cuts made upon the same or similar discs by the same knife-edge and piston when subjected to known pressure in a testing machine. It is assumed that equal pressure in the machine and in the gun will produce equal effects upon the copper discs. As will be explained later, this assumption involves an error.

SPIRAL




The Woodbridge gauge differs from the Rodman in the cutter employed. The knife-edge of the Rodman system is replaced by a narrow groove, with a cutting edge, running spirally around a concave conical surface on the end of the piston. The outer rim of this surface is in contact with the circumference of the copper disc when the gauge is ready for use. As the piston is forced in upon the disc by the pressure of discharge, the disc is compressed from its circumference towards its centre, the amount of compression being indicated by the length of the spiral cutting edge, which leaves its mark upon the disc. This record is compared with that made upon similar discs by the same piston acting under known forces.

CRUSHER



In the crusher gauge, the cutters of the two preceding systems are discarded. The piston head is plain, and between it and the base plug of the gauge is placed a copper cylinder whose length is accurately measured before and after firing. The amount by which it is found to have been shortened measures the pressure to which it has been subjected—a comparison being made as in the Rodman and Woodbridge gauges, with the effect produced by known pressure applied in a testing machine.

The Rodman gauge is used in official experiments in Germany, Russia and Italy. The crusher is used in France and England, and both the crusher and Woodbridge are used in this country.

In ordinary work, chamber pressures only are recorded. For these the gauge is inserted in the face of the mushroom or breech block, or, with a muzzle-loading gun, in a plug fitted to the rear of the powder chamber.

In special experiments, gauges are frequently used in the walls of the gun along the sides of the chamber and the bore.

They are sometimes also screwed into the base of the projectile, but here their record is modified by the motion of the projectile, and to an extent varying with every change in the amount or kind of the powder used.

The following sources of inaccuracy are inherent to all systems relying upon the deformation of metals for the measure of a pressure acting under the conditions which obtain in the bore of a gun:

First. There is a wide difference between the effect which a given pressure will produce when applied more or less slowly, as in a testing machine, and that which the same pressure will produce if applied suddenly, as in the explosion of confined gunpowder.

If in the testing machine the force were applied very gradually, and if in the gun the gases were evolved instantaneously, the ratio between the effects produced would be as two to one—the effect in the gun being two. This extreme case is far from existing, both because, by appropriate arrangements, the action of the machine may be made very sudden, and because the development of the maximum pressure of the powder gas is not instantaneous. Nevertheless, there undoubtedly does exist a difference which, whether large or small, tends to make the indications of the gauge higher than the pressure which has actually existed in the gun.

It should be noted, however, that the pressure is exerted upon the walls of the chamber exactly as it is felt by a pressure gauge in the chamber, so that the real strain upon the gun is that which is shown by the gauge, and not that which would be deduced from a theoretical consideration of the tension of the gases.

Second. In the deformation of a metal, whether by cutting or crushing, the element of time necessarily enters. Up to a certain point the effect will increase with the time.

In a testing machine, the force applied has time to produce its full effect; in a gun the pressure is relieved as suddenly as it is developed. It is not possible to estimate very accurately the time through which the maximum pressure acts, but it probably does not exceed, with the slowest powder, the one-thousandth part of a second.

This consideration would lead to the conclusion that the pressures recorded, when interpreted by comparison with the work of a testing machine, are too low. This source of error and the preceding one, then, tend in opposite directions, and to a certain extent offset each other. They would both be reduced to zero if, at the instant when the pressure is at a maximum, it and the force opposed to it by the resistance of the copper discs to deformation were in perfect equilibrium. Such a condition is approached by the device, commonly resorted to in practice, of subjecting the discs which are to be used in experiment to a preliminary pressure slightly lower than that which is anticipated from the firing.

This reduces, but does not remove, the difficulty. Of the error remaining, that part due to the suddenness with which the pressure is applied will be much greater with gauges placed in the path of the projectile forward of the force band than with any others. These are suddenly unmasked by the motion of the projectile to a pressure already developed, which thus comes upon them with the full force of a blow, so that the pressure which they record is doubtless considerably above the tension actually existing. Thus, of two gauges separated from each other by a few inches, but of which one stands in rear of the force band and the other in front of it, the second may give a record several tons higher than that of the first. That this is not a point of theoretical importance only has been abundantly shown in several foreign experiments, notably in those of the English Ordnance Committee of 1875, and more recently in those of Russian officers at Aboukhoff, and of French officers at Gavres. In all of these cases the crusher gauges half a calibre forward of the force band read from twenty per cent. to forty per cent. higher than those in the chamber. With regard to the bearing of these facts upon the strength of guns, it should be considered that, so long as the surface of the bore is continuous, the pressure will be communicated by the elasticity of the metal somewhat in advance of the force band, and no point will receive a sudden blow. At any break, however, which may occur at the continuity of the bore—as, for instance, where the two parts of a tube butt together—there will be an interruption of the transmission of pressure in front of the band. No strain will be felt by that part of the tube forward of the break until the force band has passed it, when the full pressure of the gas will come upon it with a blow, exactly as it would come upon a pressure gauge at that point; and the strain tending to rupture the gun will be just double what it would be if the fibres of the bore were continuous.

This would seem to be a point of weakness in those systems of gun construction in which the tube is composed of two lengths, or in which a liner is inserted which does not extend to the muzzle. It would seem also to furnish an additional reason for the use of a highly elastic steel.

The Deprez manometric balance resembles the instruments already described in opposing a known resistance to the work of the powder gases, but differs from them in the nature of the resistance.

It consists of a piston with a large and a small head connected by a stem running through the wall of the gun. The small head stands flush with the face of the bore, and is acted upon like the piston heads of the gauges already

described, by the gases in the gun. The large head is outside the gun and is enclosed by an air chamber, in which it is placed under a known pressure of air. The ratio between the areas of the piston heads is 1 to 400.

Before the gun is fired, the air pressure holds the larger piston head firmly down, binding a small strip of metal between its lower face and a flat plate which forms part of the gauge. A powerful spring attached to the metal strip seeks to draw it out, but can start it only on condition that the piston of the gauge is lifted. If, when the gun is fired, the pressure developed in the bore and exerted upon the small head of the piston exceeds that of the air upon the larger head, the piston will be lifted and the metal strip released. Knowing, then, in any case, the pressure of the air, we can tell of the pressure in the bore, not what it has been, but whether it has or has not exceeded a certain known amount.

By repeating the experiment with constant conditions of powder, projectile, etc., but with varying pressure in the air chamber, it is possible to arrive at a close approximation to the pressure in the bore. It should be added that by an electrical attachment the starting of the metal strip is registered automatically, and that in practice a number of gauges with different pressures are used in a single experiment.

Of instruments which measure pressure by work done in imparting motion, the most important are the Noble chronoscope, the Sébert velocimetre, and the Sébert self-registering projectile.

The Noble chronoscope was used, in connection with crusher gauges, by the English Ordnance Committee which, between 1875 and 1877, conducted a series of experiments upon the action of fired gunpowder. It records the velocity of the projectile at successive intervals of its path in the bore, from which the accelerations, and hence the pressures corresponding, can be deduced. A number of plugs are inserted in the wall of the gun at points forward of the base of the projectile, each plug carrying a small wire which forms part of an electric circuit communicating with a delicate time-recording instrument or chronoscope. When the plugs are in place in the gun, their inner ends, carrying the wires which, as already explained, are in circuit with the recording instrument, stand just inside the bore. The wires are cut in succession by the projectile as it passes through the bore, each circuit, as it is broken, leaving a record upon the cylinder of the chronoscope.

The distances between the plugs being known, and the interval of time between the cutting of any two, the velocity between those two is known, and the pressure acting to produce the successive accelerations can be deduced.

In the Sébert velocimetre the acceleration in velocity of recoil of the gun at a given instant is made the measure of the pressure acting in the bore at that instant.

A ribbon of flexible metal, thinly coated with lampblack, is attached to the gun and moves with it. Above the ribbon stands a tuning-fork, suspended between two electro-magnets. A small spring attached to and vibrating with the tuning-fork makes and breaks the circuits of the electro-magnets so that

the latter are magnetized and demagnetized very rapidly, and the tuning-fork is attracted alternately to one side and the other. Thus, after a single instant of initial vibration given to the fork, its motion is controlled by the electro-magnets, and will remain constant as long as the strength of the magnets remains constant.

To one of the branches of the tuning-fork is attached a small pencil, held in light contact with the blackened surface of the flexible ribbon. If the fork be started vibrating while the ribbon is at rest, the pencil will trace a line at right angles to the length of the ribbon. As the gun starts to the rear upon firing, the ribbon is drawn out under the tuning-fork and the line traced by the pencil becomes sinuous. From its direction at any given point, knowing the velocity of vibration of the fork, we can determine the velocity of recoil corresponding to that point. From velocities at successive points are deduced accelerations between those points, and from these are derived the pressures acting in the bore; provided that we have an accurate knowledge not only of the mass of the gun and carriage, but also of the resistance acting in opposition to the recoil.

The Sébert self-registering projectile is a hollow shell, through the centre of which runs a steel rod, square in section, and covered on one of its four sides with a coating of lampblack.

Loosely attached to this rod, and sliding freely upon it, is a block of metal carrying a tuning-fork, to one of the branches of which is fitted a pencil, held lightly in contact with the blackened face of the square rod.

In preparing the projectile for firing, the sliding block is brought to the forward end of the rod, and the branches of the tuning-fork are spread and held apart by a small lug on the rod. Thus prepared, the projectile is placed in the gun like an ordinary shell, and the gun fired. As the projectile starts forward, the sliding block, to which the tuning-fork is fixed, by virtue of its inertia remains at rest, the stem on which it moves sliding through it. At the first instant of motion the lug is withdrawn from between the branches of the tuning-fork, and the latter begins to vibrate at right angles to the direction of the blackened rod, which is slipping past it with the velocity of translation of the projectile. The pencil fixed to the fork thus traces a sinuous line upon the surface of the rod, the direction of which, at any given point, shows the ratio between the velocity of translation of the projectile and the velocity of vibration of the tuning-fork at that point.

It is assumed that friction between the rod and the sliding block is entirely overcome, as practically it is, so that the length of the central rod which has passed the pencil at any given instant is equal to the distance which the projectile has moved up to that instant. From the accelerations indicated by the increase in velocity, the pressures acting on the base of the projectile are deduced—neglecting that part of the work done which is absorbed in friction in the bore and in imparting rotation to the projectile.

As the length of the rod on which the record is made is limited by the length of the projectile, this method can give only the pressures corresponding to the motion of the projectile through something less than its own length. This difficulty has been overcome by a modification of the method in which a second

block is set in motion at the forward end of the rod when the first block reaches the base of the projectile.

In the early part of this paper it was stated of the three gauges whose indications depend upon the deformation of metals, that they were subject to sources of error which were reduced, but not entirely removed, by certain precautions commonly taken in practice. It will be interesting, before closing, to inquire how far these errors probably impair the accuracy of results based upon the indications of such gauges; the more so as crusher gauges placed in the powder chamber have been used in the tests of the new Navy guns and powder.

It is sometimes stated that while the indications of such gauges are reliable for *comparisons* of pressure, they are not to be trusted for absolute values.

This subject has been very elaborately investigated by the eminent French artillerist and mathematician, Monsieur E. Sarrau, who concludes, as the result of his experiments, that the indications of crusher gauges in the powder chamber are practically correct, not only comparatively but absolutely, the errors due to the manner in which the pressure is applied being within the limits of accuracy of the instrument.

With gauges forward of the band slope the case is quite different, and here he concludes that the indications of the gauges are much too high, and altogether unreliable for ballistic calculations.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

# ON THE STUDY OF NAVAL HISTORY.*

## (GRAND TACTICS.)

By Rear-Admiral S. B. Luce, U. S. N.

### INTRODUCTORY.

The term "Naval Tactics" has been used in such a general way as to lead to some confusion of ideas regarding its true meaning. Some writers restrict it to the evolutionary movements of a fleet, and such as are to be found in the Tactical Signal Book; others limit it to the manner of conducting a fleet in battle; while others again use the term in both senses, and often in such a careless way as to lead themselves and their readers into no little confusion. It is just as well that we should, in the very beginning, fully understand an expression which promises to be of frequent use.

Tactics has been well defined as the art of military movements. Naval Tactics is the art of conducting *the military movements of a fleet.* Battle being the chief object and end of a fleet, the order of battle constitutes the principal formation; and to bring the vessels composing a fleet, from any given order, to the order of battle, or any other order, is to perform an evolutionary or tactical movement. There are, besides the order of battle, various other orders and movements—such as chasing an enemy's fleet; escaping from a superior force; protecting a convoy; navigating the high seas; anchoring; going in or out of port, etc., etc.

These several orders, or formations, formerly called the "orders of sailing," etc., etc., were laid down in the Signal Book; and the methods of changing from one order to another were fully prescribed, a diagram accompanying each evolutionary signal number, showing the positions and movements of each individual ship. Thus, when, in 1790, Admiral Lord Howe rearranged the Signal Book of the

* Read at the Naval War College, September, 1886.

English Navy, he introduced "instructions for the conduct of the fleet in the execution of the principal evolutions which were illustrated by figures." These evolutions may be termed Elementary or Minor Tactics. In thus revising the Signal Book, Lord Howe rendered a great service to the English Navy, and the value of his work was generously acknowledged by Nelson. In his letter to Earl Howe of January 8, 1799, giving some account of the battle of the Nile, Nelson writes: "This plan" (of battle) "my friends" (the captains of the several ships composing the fleet) "readily conceived by the signals, for which we are principally, if not entirely, indebted to Your Lordship. . . . ." Later on in the same letter he speaks of Earl Howe as "our great master in naval tactics and bravery." The term "naval tactics," as here used by Nelson, is undoubtedly to be taken in connection with the revised Code of Signals, and refers to the Manual of Fleet Evolutions, which had been rearranged by Howe. Howe not only revised and greatly improved the Signal Book of the English Navy, including the Code of Tactical Signals, but he enjoyed the reputation of being indefatigable in the exercising of the fleet under his command in tactical evolutions, and the transmitting of orders by signals. He was, moreover, very exacting, requiring great precision in the execution of all manœuvres. But this seems to be the limit of Howe's claim to be considered a tactician. He was skillful in Minor Tactics.

While Nelson was giving credit to Howe for a code of Minor Tactics, he, himself, was developing a system of Fighting Tactics (as it was formerly termed) till then little known in the English Navy. It was a system based upon sound military principles: that of beating the enemy in detail. In the letter just quoted, Nelson gives the gist of his plan of attack at the Nile. He says: "By attacking the enemy's van and centre, the wind blowing along their line, I was enabled to throw what force I pleased on a few ships." And it is this idea of placing two ships on one of the enemy, of doubling on him, that constitutes the merit of Nelson's fighting tactics.

Here, then, we have two celebrated tacticians. First, Howe, constantly exercising the fleet in Minor or Elementary Tactics, and preparing a school of officers who were subsequently to second Nelson in the development of the higher school of Grand Tactics; and, secondly, Nelson, who may be said to have founded a school of Grand Tactics. For it should be remembered that in Howe's great battle of the first of June (1794), he exhibited no such fighting

tactics as was afterwards practised by Nelson. With his accustomed exactness he formed his line with great precision, and stood down for the French fleet, each ship steering for her opposite, with the intention that all should pass through and haul to the wind, to leeward of the French line. There is no hint of crushing any one part of the enemy's force by overwhelming numbers; no indication of an intention of doubling on the van, or centre, or of placing the enemy between two fires. It was simply the old custom of placing ship against ship, and allowing a great fleet fight to resolve itself into a series of single engagements. The result was the customary indecisive battle, and consequent popular dissatisfaction. Howe, then, was not a tactician in the sense that Nelson was.

These two distinguished officers therefore represent the two different branches: the first Minor, Elementary, or Evolutionary Tactics; the second Fighting or Grand Tactics, or the Tactics of Battle. These two branches, so inseparably connected, and which together with Strategy form one science, should, for the purpose of our present studies, be held separate and distinct. Nelson was also a great strategist; but this again is a distinct branch, which will be considered further on. At present we have to do with Grand Tactics alone—that is to say, with Fleet Fighting and its history.

The Signal Book furnishes, as already observed, the necessary instruction in the evolutions of a fleet. But there is no recognized code of Grand Tactics. In the early days of sailing tactics the navies of England and France had their Fighting Instructions, the latter contained in the Ordonnance du Roi. But it is quite safe to say that no navy of the present day can claim what may be called a satisfactory system of Fighting Instructions; or, we might go so far as to say, a satisfactory fleet organization. It is in the hope of obtaining clear ideas of the latter, so as to enable us to organize a fleet on sound principles, that one part of our studies is to be directed. Another essential part is to study the great sea fights of history, that we may form clear conceptions of how to fight the fleet we have organized. This is our present business.

The plan of attack drawn up by Nelson during his pursuit of the French fleet to the West Indies contains the general principles which guided him in all his battles; principles which are in perfect harmony with the Science of War, and just as applicable now as they were then. In his memoranda he begins by enunciating the broad principle that it is the business of a commander-in-chief "to bring

an enemy's fleet to battle on the most advantageous terms." One of these advantages he states to be "close action"; in other words, that the enemy is to be brought within effective range of his guns. He next assumes that the admirals and captains of the fleet will thoroughly understand his plan of battle; and, therefore, that few signals will be necessary.

This last expression has been, we may here remark parenthetically, misapplied and misunderstood.

Nelson closed the Signal Book because, having made his dispositions with great care beforehand, and fully instructed his captains as to his plan of battle, signals were no longer necessary. Battle once joined, every one was trusted to carry out his allotted part of the general plan.

Howe closed the Signal Book because he had no plan of battle beyond the simple method of the barbarian, to pit ship against ship.

It is easy to understand, therefore, how, when the opponents were fairly matched in military force, the results could be decisive in the former case and indecisive in the latter.

Having defined and illustrated the two branches of Naval Tactics, let us now take a cursory view of its history.

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In the ardor of pursuit of a new study, such as we have declared "Naval Warfare under Steam" to be, we must not be unmindful of the lessons of the past. "History," it has been well said, "is Philosophy teaching by example." We may add that history admonishes by its warnings. It is by the knowledge derived from the history of naval battles that we will be enabled to establish a number of facts on which to generalize and formulate those principles which are to constitute the groundwork of our new science.

"History, as a means of instruction in the art of war, is obviously of the highest value," observes one military writer. "But," he adds, "to make the study of history profitable, the mind ought, in the first instance, to be prepared so as rightly to distinguish between military events which may be analyzed and reasoned upon with advantage, and those which may be regarded merely as events in the world's history destitute of any important bearing on the art of war." It is only by a philosophical study of military and naval history that we can discover those truths upon which we are to generalize. "Thus," as the writer just quoted states, "the victory at Wagram has been

traced to the same primary cause by which the battles of Cannæ and Pharsalia were gained, and the existence of fundamental principles, by which all the operations of war should be conducted, has been placed beyond doubt by the researches of Jomini and other military writers." What has been done for military science is yet to be done for naval science. In the pride of an advanced civilization, we are too apt to look with contempt upon the old sailing tactics, and the battles fought under them. But even in these days of steam and electricity we may study with advantage the works not only of John Clerk and Paul Hoste, but of Thucydides and Herodotus.

Minor Tactics change with the change of arms or improvements in naval architecture.

Not so with Grand Tactics. But whether it was Phormio or Agrippa or Russell, a Nelson or a Perry, the victory has generally been with that leader who had the skill to throw two or more of his own ships upon one of the enemy. That is one of the most valuable lessons of all naval history, and that, it may be stated here, is one of the fundamental principles of our science. It is the capacity to carry out that principle that gives evidence of the skillful tactician. It is the ignoring of that principle that serves as one of the most impressive warnings of naval history.

Strategy is still less affected by the mutations of time and the advance of learning. Alexander the Great found it impracticable to reduce Tyre without the aid of a fleet. On the appearance of the Cyprian and Phœnician war galleys, the Tyrians called in their own vessels and sunk triremes in the channel ways to block the entrance to their harbors. Twenty-two centuries later the combined fleets of England and France, co-operating with the armies on shore, compelled the Russians to resort to the same expedient; that is, to close the harbor of Sebastopol by sinking vessels of war in the entrance. The Persian invasion of Greece taught the Athenians the necessity of having a navy. A navy was built, and at Salamis proved the salvation of the State.

England taught the United States the same lesson. Great strategic combinations it was found could not be formed without a navy; a navy was created—a navy small in numbers, but great in spirit—and the victories on Lake Erie and Lake Champlain proved its inestimable value. History is full of such parallels. The invasion of Britain was once rendered possible by reason of the strength of the Roman fleet. But from the time of the Invincible Armada to the day of Trafalgar

it has been impossible through the constancy and devotion of the English Channel Fleet. And although there have been such radical changes in the means of carrying on naval warfare, yet the same strategy which enticed Nelson to the West Indies in the vain pursuit of the French Fleet might be practised again to-day.

There are certain general principles which are just as applicable to the management of a sea army of the nineteenth century as they were in the days of Salamis or Actium, of Trafalgar or Lake Erie. Hence, it may be stated in general terms that, while the principles of the Science of War remain unchanged, the rules of the Art of War vary with the implements of war.

The introduction of the rules of the military art into the conduct of a fleet, and the revival of the spur, the rostrum of the galley period, has not only brought us back to the same general system of tactics in use during the ancient civilization, but has rendered a quasi-military education indispensable to the naval officer.

The great captains who achieved success at the head of the armies of Greece and of Rome, carried with them their fighting tactics to the fleet, and on the decks of their galleys won the *corona navalis* for victories due to their military skill.*

It was so in the Middle Ages. King Edward III., who was distinguished for his military abilities, defeated the French in the great battle of Sluys—a battle which, for the skillful manner in which it was fought, was thought worthy to be compared to the masterpieces of the ancient Athenian navy.

It was so at the dawn of modern civilization. Don John of Austria, who was essentially a soldier, gained at Lepanto one of the greatest naval battles of history.

It was so during the earlier period of English naval history. Blake, Monk, Popham, Deane, Prince Rupert and the Duke of York, all of whom held the highest commands during those terrible contests with the Dutch for the mastery of the narrow seas, were all men of military training. It was absolutely necessary, indeed, that men of military capacity should control the military movements of those large fleets on which the very existence of England depended, for the naval officer of that day knew little beyond the mere rudiments of his calling as a seaman.

* In Vol. III., No. 1 (April 20, 1876), of the Record of the U. S. Naval Institute, an attempt was made to show more in detail than is now necessary the formation common to the fleets and armies of the Oar Period.

As the navy of England developed into a distinct profession, the officers were sent to sea at a very early age and kept actively engaged, that they might become inured to the hardships and privations of ship life. With many undoubted advantages, the custom was open to certain objections. While it made them good, practical seamen, it gave them the sailor's proverbial distaste for acquiring knowledge through the medium of books. Thus they came to excel in all the practical details of their profession, but they knew little of the theory, or general principles, on which the science of that profession was based. To handle a ship in a seamanlike manner, and to preserve one's station in the fleet, seems to have been the highest point to which the practical education of that day aspired. True, that was much—indeed, it was a great deal; the value of that instruction was scarcely to be overestimated. When we consider the size of the fleets; their protracted cruises; their long and tedious blockades through all the changes of seasons; the vicissitudes of weather, and the very poor sailing qualities of many or most of the ships before copper sheathing came into use, we cannot withhold our wonder and admiration for the skill, the devotion and courage of the English naval officers during those long naval wars which fill so large a space in the English history. But that severe school of practice, thorough as it undoubtedly was, proved wholly insufficient. The constant employment of the officers at sea, and the absence of a higher school, were an effectual bar to their acquiring even the rudiments of the military art. Generation after generation of English naval officers passed without the slightest attempt at methodical instruction in naval tactics. Such knowledge of the art as was acquired must have been by the process of absorption through observing the evolutions of the fleet and the manœuvres of one's own ship. The Signal Book was the only manual of evolutions; and that was sedulously guarded from the eyes of the profane. For fear it might fall into the hands of the enemy, as it did on one or two notable occasions, or be surreptitiously copied by traitorous hands, it was heavily weighted with lead; and, when not in actual use, kept within the sacred precincts of the captain's cabin, whence none but the elect might take it. In the event of defeat it was to be cast into the sea. Furthermore, the flag officers of the English Navy were, for over a century, heavily handicapped by the Fighting Instructions of 1665, which prescribed certain rules for the conduct of a fleet in battle—rules which proved to be not of general application, and not always in harmony with the prin-

ciples of war. Unfortunately, these rules, insufficient as they were, received full confirmation by the mature judgment of two courts-martial which may be numbered among the *causes célèbres* of the English Navy. The first was that of Admiral Thomas Mathews for his failure in the engagement with the Franco-Spanish fleet off Toulon in the spring of 1744. The second was the trial of Admiral John Byng for his failure in the battle with the French fleet off Minorca in May, 1756.

The Instructions, on which, in a great measure, the judgment of the court in each case turned, were drawn up by the Duke of York (James II.) in 1665. (See "Fleets of the World," No. 1, Vol. III., of Record of U. S. Naval Institute, before alluded to.)

This was during those severe contests with the Dutch for the mastery of the narrow seas in which the conflicts took place. The line of battle, which was then for the first time observed according to Paul Hoste, though certain authors maintain that it was known previously by the Dutch, consisted of the close-hauled line ahead, in practice seven points from the wind. Owing to the limited sea room and the dangerous coasts, the weather gauge was of the very first importance, and as a consequence it was necessary to preserve the order of battle with some degree of precision. When the field of operations was transferred to the broad ocean these conditions became greatly modified; yet, notwithstanding this, the Instructions continued to be binding, and were blindly observed to the frequent discomfiture of the English Navy. Thus, in Mathews' fight off Toulon, his vice-admiral, Lestock, accused him of "rashness and precipitation in engaging the enemy before the line of battle was formed, contrary to the rules of war and the *practice of our best admirals;* therefore the sole miscarriage was chargeable on the admiral, who, by his imprudence in fighting, at first, at such a disadvantage, had endangered the whole fleet; and after, by a quite contrary conduct, suffered the enemy to escape."

Mathews, though he had exhibited the highest gallantry, was found guilty and declared to be "incapable of holding any further employment in His Majesty's service."

Byng, on the other hand, failed from a too strict observance of the line of battle. Warned by the result of the former court-martial, he declared at the commencement of the battle that he "would not fall into that error with which Mr. Mathews was charged, and which proved his ruin," that of engaging the enemy before his line of battle

was formed. He was found guilty of the charges brought against him and condemned to death. He was said to have been "too great an observer of forms, of ancient rules of discipline and naval etiquette."

During the Dutch wars the opposing fleets were no sooner out of port than they sighted each other; nor was it likely that the men who destroyed the shipping in the Thames, and whose guns were heard in London, would waste much time in manœuvring. Battle was joined with eagerness on both sides, and the fighting was of the most stubborn character. But on the broad Atlantic, or even in the Mediterranean, fleets might cruise week after week without falling in with each other. When they did the English instinctively manœuvred, as they had done in the Channel, for a windward position, which the French, committed to a different policy, and hampered by no such traditions, readily yielded. If the two fleets were on the same tack, and on parallel lines, the French would reduce sail, and under easy canvas await the enemy. If he came up astern, the van division of the English would first engage the rear of the French. The English could not use the lower-deck batteries in a fresh breeze, while the French, using their weather guns, could get all the elevation they needed. Firing high, they cut away the spars, rigging and sail of the English, which reduced their speed and threw the head of the line into confusion. Or, if the distance between the two lines was beyond the range of their guns, the English would stand on till the leading ships were abreast of each other, when they would run down to engage, each ship selecting her antagonist. But while they were standing down for the French, the latter would keep up a constant fire, raking their enemies as they approached; the English, meanwhile, unable to bring but a few bow guns to bear. When the English "brought by the wind," so as to use their broadsides, the French would bear up, make sail, and, running to leeward, reform their line and await another attack; this, the English, by being cut up by the French fire, were seldom able to make. Or, the two fleets might cross on opposite tacks, firing distant broadsides in passing. Again, the French Government had early submitted the various problems which enter into shipbuilding to rigid mathematical discussion at the hands of their most eminent mathematicians. The French ships, therefore, were superior to the English in the essential quality of speed, and the French naval authorities had recognized at the very first the necessity of sheathing their ships with metal. For

these reasons the French admirals found no difficulty in avoiding a battle when it did not suit their purpose to fight; and, as the resources of their country did not enable them to build and fit out ships with the rapidity with which it could be done in England, it was their policy to avoid decisive actions unless the chances were greatly in their favor; hence, it frequently occurred that they declined to bring on a general engagement.

The many indecisive battles which resulted from these several causes gave great dissatisfaction in England, and finally culminated in the court-martial of Admiral Keppel for his failure in the battle off Ushant in 1778.

As in the case of Mathews, the charges were brought by his vice-admiral (Sir Hugh Palliser), the second in command, and mainly for the same reason. The first charge declared in effect "that on the morning of the 27th of July, 1778, having a fleet of thirty ships of the line under his command, and being in the presence of a French fleet of a like number of ships of the line, the said admiral (Keppel) did not put his fleet in the line of battle, or into any order proper for receiving or attacking an enemy; but, on the contrary, by making signal for several ships to chase, increased the disorder of his fleet, and whilst in the disorder he advanced to the enemy and made signal for battle, the enemy's fleet being formed in a regular line of battle on that tack which approached the British fleet. By this unofficer-like conduct a general engagement was not brought about," etc., etc.

A brief abstract from Admiral Keppel's defense will show the line of his argument: "On my first discovering the French fleet at 1 P.M., July 23d, I made signal to form the order of battle, which being effected towards evening, the fleet was 'brought to' till morning, when, perceiving the French had gained the wind during the night, and carried a pressed sail to preserve it, I discontinued the signal for the time and made signal to chase to windward. If, by obstinately adhering to the line of battle, I had suffered the French to have separated from me; if the expected convoys had been cut off, or the coast of England had been insulted, what would have been my situation? Supported by the examples of Admiral Russel and other great naval commanders, who in similar situations had ever made strict order give way to reasonable enterprise, and particularly of Lord Hawke, who, rejecting all rules and forms, grasped at victory by an irregular attack,* I determined not to lose sight of the French fleet by being

*Alluding, no doubt, to the battle of Quiberon in 1759.

outsailed, from preserving the line of battle," etc., etc. The court found the charges malicious and ill-founded.

In his official report of the battle the admiral had said: "The object of the French seemed to be the disabling of the King's ships in their masts and sails, in which they so far succeeded as to prevent many of the ships of my fleet being able to follow me, when I wore to stand after the French fleet. They took advantage of the night and made off. The wind and weather being such that they could reach their own shores before there was any chance of the King's fleet getting up with them, the state the ships were in—in their masts, yards and sails—left me no choice of what was proper and advisable to do." That was to return to Plymouth. The opinion of D'Orvilliers, the French admiral who had been opposed to Keppel, is valuable: "During the fight," said he, "the English had the advantage, but after the firing ceased I out-manoeuvred Mr. Keppel."

The insignificant result of the battle and the court-martial which followed created great interest in England. But of the flood of literature that was poured upon the subject, the only publication that concerns us now is the pamphlet printed for private circulation by the Scotch country gentleman named John Clerk.* Up to his time there had been so many great battles the results of which were wholly out of proportion to the numbers engaged, that Clerk was led to believe the French "had discovered some new system of tactics; and that the English practice, since it was always unsuccessful, must have been radically wrong."

In his more elaborate treatise, which appeared in 1790, he states that "after an examination of the late engagements it will be found that the French have never shown a willingness to risk making an attack, but have invariably made a choice of the leeward position; and when extended in line of battle they have disabled the English fleets in coming down to the attack. Upon seeing the English fleet disabled, they have made sail and demolished the van in passing, and upon feeling the effect of the English fire they have withdrawn, at pleasure, either a part or the whole of their fleet, and formed a new line of battle to leeward. The French have repeatedly done this. It will be found, on the other hand, that the English, from an irresist-

* See "Life of John Clerk" by the eminent Scotch professor, Playfair. Clerk seems to have had a natural capacity for military affairs. Disappointed in his early hopes of entering the Navy, he gave much time to the study of Naval Tactics.

ible desire of making the attack, have as constantly courted the windward position, and have repeatedly had their ships so disabled, by making the attack, that they have not once been able to bring them to close with, to follow up, or even to detain, one ship of the enemy. Therefore there was every reason to believe that the French had adopted and put in execution some system which the English either had not discovered, or had not yet profited by the discovery."

To illustrate his position he cites a number of cases, such as Byng's unfortunate action, already referred to; Pocock's battles with M. D'Aché in the East Indies in 1757; Admiral Byron's engagement off Granada in 1779; Arbuthnot's off the Capes of Virginia in 1781, and that of Graves about the same time and place. The last instance in the series is Lord Rodney's engagement off Martinique, April 17, 1780: "Notwithstanding the personal gallantry of Lord Rodney the French fleet bore alternately away and escaped, while the English, from the damage sustained in hulls and rigging, were unable to continue the pursuit."

Clerk further undertakes to show that whenever the French kept to windward, they were careful never to take the initiative and seek a battle, unless the odds were clearly in their favor.

This is illustrated by Rodney's two engagements on the 15th and 19th of May, 1780, near Martinique; Sir Saml. Hood's engagement of the 17th of April, 1781, near the same place, and by Admiral Keppel's in 1778 off Ushant, already referred to. In each of these fights the fleets crossed on opposite tacks, exchanging their fire in passing. In the last case the French fleet, having the wind, ran down and reformed to leeward. Subsequently, in Arbuthnot's fight off the Chesapeake, the French admiral put in practice the same tactics. "It is by such investigations only," he says, "that it can be explained how two adverse fleets, amounting to thirty ships of the line each, carrying above 36,000 men, after having been brought in opposition of battle, and sustaining a furious cannonade from 4000 guns, besides musketry, have been brought to be separated again without effect, without the smallest apparent decision—that is, without the loss of a ship on either side, and sometimes without the loss of a man, although the rencounter has often been said to have been within pistol-shot."

On board the Ramilies,* Admiral Byng's flagship, in the fight with the French off Toulon, no one was even wounded.

* Read the account of the loss of the Ramilies in 1782 with Admiral Graves on board. She was hove to under the mainsail on the larboard tack. The admiral was saved and all the crew.

Such, says an able English authority, in commenting upon Clerk's essay, was the state of Naval Tactics at the beginning of 1782. "During the whole war our fleets had invariably been baffled, disabled, worsted. Our admirals adhered, invariably, to the established mode of attack, and endeavored to obtain a windward position before they began to engage. The French, relying upon our want of penetration to discover, or of skill to counteract, this new system of defense, never failed to accomplish the object of their expedition, and to disable our ships, while they preserved their own. Dispirited by the failure of our arms in the American war, we beheld ourselves uniformly baffled on our own element, and we began to apprehend a decay of spirit in our officers and seamen." When we consider that this language was used by McArthur, the author of the well-known treatise on Naval Courts-Martial, and at one time Secretary to Admiral Lord Hood, it will add not a little to its significance.

Rear-Admiral Sir Charles Ekins remarks of Clerk: "In all his reasoning he shows with truth and success that our defeats were never owing to a want of spirit, but to *a deficiency of tactical knowledge.*"

"No lessons in tactics," says one of the ablest naval essayists of the present day, "can be so valuable as those taught by the experience of the past. In no case has a victory been won over a fairly equal force where the ignorance of the one commander-in-chief, or the skill of the others, has caused the strength of the fleet to be dispersed and has spread the attack over the whole, instead of concentrating it against a part."

"All the painfully notorious battles of the last century—notorious by reason of the bitter feeling and angry, tragical courts-martial which followed their want of success—come distinctly under this category. From the time of Mathews to the time of Rodney we were trammeled and bound to a false system which, when skilfully opposed, could not, and did not, lead to any results other than disappointment and loss. The attack was made in line against line, if possible, ship against ship; and in no one instance was it attended with success. That the individual ships were, for the most part, skilfully handled and gallantly fought, may be conceded; that they were, singly, superior to the ships of the enemy, may be fairly maintained, but *collectively and as a fleet they were unable to accomplish anything.*" *

* Prof. John Knox Laughton, R. N., Royal Naval College, Greenwich, to whom we are indebted for many valuable lessons.—S. B. L.

These are certainly very candid admissions; but they are fully justified by history.

Coming to us, as they do, from authors of high standing and of intimate knowledge of the subject, these statements are of the utmost value to the naval student; and we cannot feel too grateful to those gentlemen who have had the enlightened spirit, the sense of justice, and the love of truth, to give the plain facts, though it should not always redound to the credit of the profession they so worthily represent.

We now come to the true cause of the difficulty under which the English labored, and to the secret of the so-called "new system" devised by the French. McArthur goes on to say, "Our officers were eminently distinguished by their gallantry and seamanship, *but they had hitherto bestowed no adequate degree of attention upon Naval Tactics.*" And yet, for the fifty years preceding the treaty of Paris of 1783, the English naval officers had been constantly engaged in war.*

French officers, on the other hand, seem to have paid great attention to Naval Tactics. Tourville, so highly eulogized by Macaulay, originated the best work on Naval Tactics (that of Paul Hoste) ever published.

D'Orvilliers, who fought the drawn battle with Keppel, was the author of a work on Tactics; and the Viscount de Grenier proposed a formation for battle and a system of tactics which was certainly a work of merit. The Viscount Morogues and others of more or less note had written on the same subject. Ramatuelle is worthy of careful study to-day.

Ramatuelle † observes: "The French Navy has always preferred

* However fully we may share the incredulity of Lieutenant Hatchway, there is that about the utterances of Commodore Trunnion which plainly indicates the drift of popular opinion in his day (1751) in regard to the average sea-fight. In speaking of one of his exploits the Commodore says: "Finding the Frenchman—the Flower de Louse—took a great deal of drubbing, and that he had shot away all our rigging, and killed and wounded a great number of our men, I resolved to run him on board; but Monsieur, perceiving what we were about, filled his topsails and sheered off, leaving us like a log upon the water" (Dr. Smollett was a loblolly boy on board the Suffolk, Commodore, afterwards Admiral Sir Charles Knowles, and was present at the attack on La Guira in 1743. "Peregrine Pickle" first appeared in 1751.)

† Cours élémentaire de Tactique navale: Dédié à Bonaparte par Audibert Ramatuelle, ancien Officier de la Marine militaire, Paris, 1802.

the glory of securing, or retaining, a strategic advantage, or a conquest, to the more brilliant, perhaps, but really less substantial feat of making prizes; and in that they approach nearer to the true ends of war. For what would the loss of a few ships be to the English? The principal aim is to attack them in their possessions, the source of their vast commerce and their powerful marine."

The superiority of the French as tacticians is well illustrated by the battles fought by Sir George Pocock and Monsieur D'Aché in the East Indies; and, better yet, by the series of battles between the Bailli de Suffren and Sir Edward Hughes on the same station in 1782 and 1783.

Both commanders-in-chief, being remote from their respective Governments, and beyond the reach of instructions, were thrown upon their own resources, and obliged to rely solely upon their own judgment in the conduct of affairs.

De Suffren recovered the Dutch ports of Trincomalee, which the English admiral had captured a short time before, and after a series of actions raised the blockade of Cudalore and relieved the garrison. The conflicts were terminated by tidings of peace, leaving the French, on the whole, masters of the situation.

In all the higher attributes of a naval officer, save hard and persistent fighting, De Suffren proved himself to be superior to his adversary.

Still another and more familiar illustration is to be found in our own early history, when, at one of the most momentous periods of the Revolutionary War, an English admiral was fairly outgeneraled by his more skillful adversary. It was when De Grasse lured the English squadron away from the relief of Cornwallis. The late Centennial celebration at Yorktown has revived the memory of the historical incidents of that period.

At no time has the French Navy received full credit for its share in bringing a long and trying campaign to a successful termination.

While extensive preparations were being made by Washington in May, 1781, to capture New York, then occupied by the English, word was sent to De Grasse, in the West Indies, soliciting his cooperation. About the middle of May a message from De Grasse reached Newport, where a portion of the French forces and a French squadron then lay, saying that he had sailed, not for New York, but for the Chesapeake. This completely changed the whole plan of operations and made the army of Cornwallis the objective point. Con-

tinuing the demonstration against New York with a view to misleading the English commander-in-chief, the combined armies took up their march for Virginia, distant about four hundred miles, and in about one month's time came within sight of the English at Yorktown. On the [illegible] of September Washington held a consultation with De Grasse on board the Ville de Paris, when arrangements were made to prosecute the siege of Yorktown.

Clinton, meanwhile, learning that the French squadron under Count de Barras had sailed from Newport for the Chesapeake, dispatched Admiral Graves with his squadron to intercept him.

On reaching the Capes of Virginia, Graves was surprised to find the French squadron at anchor in the Bay. De Grasse, on his part, expecting to see the squadron of De Barras, was surprised to see the English ships. It was now that the skill of De Grasse displayed itself in the exercise of the highest order of strategy. He immediately proceeded to sea, and practising the policy so often resorted to by the French of allowing the English to gain the much-coveted weather gauge, he commenced a series of those indecisive actions which, as we have seen, so often characterized the naval battles of that day.

After each partial engagement the French would edge away to leeward, and reforming the line of battle in a new position, await the attack. This manœuvring was kept up for five days; the English eager for a general and decisive battle, the French luring them away from the one objective point in the whole theatre of the war, the key of the entire plan of operations so laboriously prepared by Washington and his allies. At the end of about five days, judging the squadron under De Barras to be safe, De Grasse returned to the Chesapeake.

When Graves reached the Capes, he had the mortification of finding both French squadrons at anchor in the Bay, their united forces being much superior to his own. Completely outgeneraled, he returned to New York. The last avenue of escape left open to Cornwallis being thus closed by the French fleet, the destruction of the English army became inevitable.

To estimate the value of the service rendered by the French, and the full significance of the tactics of De Grasse, we have only to suppose that Admiral Graves, instead of following the French outside the Cape, had stood up the Bay for York River and effected a junction with Cornwallis. Notwithstanding the disparity of forces, the French having twenty-four ships of the line to nineteen of the English,

he could have rendered his position so strong that the French, exercising their extreme caution, would not have ventured to attack, even when joined by De Barras with ten ships of the line. Moreover, Admiral Digby, with a squadron, shortly after arrived at New York, so that when thus reinforced the fleet of Admiral Graves consisted of twenty-seven ships. Had the English commander-in-chief succored the besieged army, as a French admiral would have done, had their relative positions been changed, it would have given an entirely different complexion to the whole campaign of Washington, if it had not completely frustrated it.

The position of Admiral Graves may be likened to that of an army interposed between the parts of an enemy's extended lines in such a way as to be able to concentrate on either one of those lines before the other could be brought to its assistance.

Napoleon practised that species of tactics, which enabled him to beat his adversary in detail with brilliant success.

In this case before us, the objective point, Yorktown, was left open, so that the English admiral, without fighting, had only to sail in between the two French squadrons, establish himself in an impregnable position on the York River and render the relief so earnestly looked for by the English army. That De Grasse, with a numerically superior force, should have avoided a conflict with the English squadron, leads to the belief that the French must have been sensible of some inherent weakness, which is not fully explained by their known inability to refit their ships or replenish stores with the thoroughness and expedition of their adversaries. No doubt De Grasse was right in saying, on the occasion of his subsequent surrender to Rodney, that the English were, in naval matters, a hundred years ahead of them. We may except, as the English have so candidly done, the practical knowledge of Naval Tactics. Their superior skill in handling their fleets was forced upon them as necessary to their existence: it was the instinct of self-preservation.

The object of Clerk, to refer once more to the "Treatise on Naval Tactics," was to point out the grave defects of the English Fighting Instructions and to suggest the remedy. There seems to be no doubt that the English naval officers profited by the lesson, and, the ice once broken, there was no longer any hesitation in putting in practice the principal suggestion thrown out by the author, and one which is conformable to one of the oldest and best-known rules of the art of war—viz.: to inflict upon the enemy a decisive blow by concentrating

an overwhelming force upon a given point of his line, thus beating him in detail. It was to just such a manœuvre that Rodney owed his success on the 12th of April, 1782. How far Rodney was indebted to Clerk for the tactics which gave him the battle, it is unnecessary to discuss. Suffice here to say that in the memoirs of that officer the claim of Clerk is wholly denied; and that Sir Howard Douglas, in an able pamphlet, claims the honor in behalf of his father, who was Rodney's flag captain. Moreover, it has been pointed out by Clerk himself that the same manœuvre was performed by De Suffren, though not with equal success, in the battle with Sir Edward Hughes off Ceylon, in the East Indies, the very same day of Rodney's victory in the West Indies (April 12, 1782). The same tactics were referred to by Paul Hoste long before. They had been practised by Count d'Estrees when, in 1673, he cut through Prince Rupert's line.

It is quite certain, however, that the essay became an accepted authority, and led to a change in the Fighting Tactics of the English Navy. Thus it came that the naval battles of the French Revolution opened a fresher and brighter chapter in the history of English Naval Tactics.

Lord Howe, upon whom devolved the labor of reorganizing the English fleet and the Signal Book, after ten years of peace, led off in 1794 with the victory of the 1st of June. This was followed by the defeat of the Spanish squadron off Cape St. Vincent in 1797, where Nelson played so conspicuous a part; and in the same year Duncan, in two irregular columns, smashed through the centre and rear of the Dutch line at Camperdown, winning a brilliant victory.

The period culminated in Nelson and Trafalgar.

It is but fair to say here that it is claimed for Hawke, and with justice, that he founded the school of which Nelson became the most brilliant exponent.—("Life of Hawke.")

The English naval officers had, at last, begun to study Naval Tactics, leaving no longer to the French the monopoly of that secret of success. It is interesting to know that Nelson not only studied Clerk's Naval Tactics, but that it was his custom to give out to his captains problems in tactics for their solution. This had the tendency of leading their thoughts into those channels best calculated to prepare them for any emergency of battle that might arise, thereby laying down in advance the foundations for victory.

As the history of naval warfare may be divided into the three great periods of *Oars*, *Sails*, and *Steam*, so it is convenient for our present

purpose to divide the history of Naval Tactics under Sail into three periods. The first begins shortly after the peace of Westphalia, 1648, which terminated the Thirty Years War, and includes the three Dutch wars, when the English and Dutch contended for the sovereignty of the seas. It was during this time that James, Duke of York, originated the Naval Tactics of the English Navy and first established a regular order of battle (page 18, Vol. III., No. 1, Record of U. S. Naval Institute). It ended in 1673 with the defeat of De Ruyter by Prince Rupert. During this period the principal commands in the English fleet were held by officers who had enjoyed the advantages of a military training, and the battles were of the most decisive character.

The second period includes the times referred to by Clerk: the War of Succession, beginning in 1712; the war with Spain in 1718; the Spanish War in 1739; the war with France in 1744; the Seven Years War, from 1756 to 1763; and the American War, ending with the treaty of Paris in 1783. During this period the fleets of England were commanded by seamen pure and simple, who, ignoring the science of their profession, permitted themselves to be hampered by a set of arbitrary and insufficient rules. The battles fought during this period were, with few exceptions, indecisive.

The third and last period is characterized by a close attention to Naval Tactics and decisive battles.

It may be said to begin with Rodney's victory in 1782, and end with Nelson and Trafalgar in 1805.

The conclusion, which is not at all strained, is that the landsman with a military training was more capable of conducting the military movements of a fleet than the mere sailor who knew nothing of the science of war.

Charnock, in speaking of the Earl of Sandwich (Admiral Montague), says that "at the age of 30 (1655), bred to the Army, he was appointed joint commander of the fleet with Blake, a man undoubtedly possessed of the highest gallantry, but, like himself, totally unacquainted with every principle of Naval Tactics; yet under these very men, even at their first outset in their new profession, the British flag spread everywhere a terror and commanded a respect which, without intending to depreciate in the smallest degree the merits of their successors, we may truly say the greatest professional skill has never yet enhanced." It is evident that their ignorance of "every principle of Naval Tactics" was amply supplied by their knowledge of Military Tactics, which enabled them to direct

those more extended movements of a fleet comprehended in the term Grand Tactics, or the Tactics of Battle.

Prince Rupert and the Duke of Albemarle (Admiral George Monk) were styled "His Majesty's Generals at Sea." Monk may have excited the mirth of his sailors by calling out, "Wheel to the right," or "left," when he wished to tack ship; but he defeated the celebrated Dutch admirals, Van Tromp and De Ruyter, and was one of the best naval administrators England has ever had. Monk, it should be said, had enjoyed, during the earlier years of his life, a short experience at sea.

On the other hand, it was said of Sir Edward Hughes, a typical officer of the middle part of the eighteenth century, that he could handle his ship to admiration, but knew little about managing a fleet. Much the same may be said of Admiral Byng. A part of the evidence given on his trial conveys a valuable lesson. Captain Gardiner, of the Ramilies, 90, the flagship of Admiral Byng, testified that "he advised Mr. Byng repeatedly to bear down, but without effect; *for that on the day of the action the admiral took entire command of the ship upon himself*"; which means that he had no conception of the duties of his high office of commander-in-chief of a fleet. So of Mathews: he understood the practical part of his profession better than the theory, and "knew better how to fight, himself, than to command others to fight."

We cannot refrain from giving here a couple of pen-and-ink portraits of two distinguished officers whose services have been referred to. Of De Suffren the writer says: "He was cool and daring in action, crafty in policy, of ready wit, and of singular genius as a tactician, with much practical skill, added to a vast fund of theoretical skill: the most illustrious officer, without exception, that had ever held command in the French Navy." Opposed to him was Sir Edward Hughes: "Brave, skilled in his profession, of the old school, not fitted to receive new ideas, opinionated, perverse, with but little idea of tactics and less of policy, he was still, at all times, ready for battle. *He did not know much about manœuvring a fleet*, but he could handle his own ship to admiration; he had not much judgment as to the proper time to fight, but when he did fight, he did so with a courage that was proof against all odds." *

Sir Charles Ekins, in commenting upon the want of success of Admiral Graves, remarks that, "unfortunately, the fate of Mathews

* Professor J. K. Laughton, R. N.

and Byng was still fresh in the recollection of our naval commanders; and as in those cases disgrace or punishment alike awaited both the daring and the cautious, the conducting of a fleet in the presence of an enemy became a duty at once perilous and perplexing."

It is curious to note, as we may here, how the traditions of the English Navy seem to have completely usurped the place of original investigation. Keppel justified his conduct as having been formed on that of Russell, Hawke, and other great commanders, and the sentences inflicted upon Mathews and Byng affected generations of their successors.

The great lesson to be drawn from this cursory review of the history of Naval Tactics under Sail is, that the highest achievements of a navy are to be secured when, to the practical training from boyhood in all the details of the naval profession, there is added proper instruction in the science and art of war.

We must pause here for a moment to disclaim any intention of undervaluing the character of those many great seamen whose deeds embellish and adorn the pages of English naval history.

Drake, Hawkins and Frobisher (Lord Howard was not a seaman in the sense that Drake was), aided by the elements, scattered the Invincible Armada; but they lived before any regular system of tactics had been devised. And Anson, Hawke and Boscawen won their victories for the most part by superior numbers, wherein skill and tactics had little part. The battle of Quiberon, fought in bad weather, on a dangerous and unknown coast, must, however, stand out as a brilliant and exceptional victory.

If history be that "vast Mississippi of falsehood" Arnold has called it, the earnest student in his search for truth must carefully weigh the evidence, for and against, before concluding on the respective merits of the Fighting Tactics of the English and the French Navies of the last period of Tactics under Sail. Much praise is undoubtedly due to Nelson and his school; but what was the condition of the French Navy during the Revolution and the Consulate? Says an English naval essayist on this point: "The French, by their careful study of, and attention to, the details of naval architecture, of strategy and tactics, held their own against us for nearly one hundred years—not brilliantly, perhaps, but at any rate sufficiently—and it was not till the close of the century, when the study of tactics had been, in a measure, *forced upon us*, that we recovered our old superiority. As we improved, the French, victims of anarchy and internal confusion, deteriorated, and

thus, by the happy combination on our part of tactical study, practical skill, and constant experience; on the part of the enemy of ignorance and presumption, we won those great victories which mark the annals of the end of the last century and the beginning of this."*

These "great victories," then, were not due wholly to the prowess and skill of the English, but in a measure to the deterioration of the French; how great a measure that was, English writers themselves tell us.

But let us continue our study of English Naval Tactics.

In 1827 was fought, at Navarino, the last great fleet fight under sail; and the year after appeared the second edition of "Naval Battles," by Rear-Admiral Ekins, from which we make the following extract. He quotes another English admiral of distinction who uses this language: "If I commanded an English fleet opposed to a French one, I should not have the least objection to their cutting my line. I should probably myself break all order of battle, in order to prevent their cutting off any particular ships, and then, behold! the old story: I have them in action, ship to ship. This is the great secret of *our* tactics; that of the French to prevent it.

"I fairly own," he continues, "that I hope close action, ship to ship, will ever be the first object of a British naval commander-in-chief." And Admiral Ekins adds, with a burst of fine enthusiasm: "This is bravely said by the gallant son of a noble chief, and let the British Navy say, *Amen!*" This may be admirable as a specimen of rhetoric, but, certainly, very poor tactics. The passage is not without value, however, as corroborative of one of two theories: Either the English had been betrayed into over-confidence by the demoralized condition of the French Navy, and the consequent ease with which victories over it were gained, rendering skillful tactics unnecessary—and there is much to support this view—or, that after Trafalgar the English Navy relapsed into what has been well called the "Dark Age" of Naval Tactics. As late as 1828 two distinguished British admirals coolly tell us that the secret of their tactics is "close action, ship to ship"—a principle directly opposite to what their own Nelson and his school taught. His teaching, and the teachings of all great captains, both on shore and afloat, is to put *two* against *one*. To understand this fundamental principle is to understand the very root and groundwork of Grand Tactics; and to be able to carry out this principle in battle, is to exhibit the highest skill as a tactician. What,

* Prof. J. K. Laughton, R. N.

then, must we say of the Ekins school? Sir Samuel Hood, with twenty-two ships, when standing in to engage the French fleet of thirty-three sail of the line under De Grasse (anchored at Basse-terre, St. Christopher, in 1772), designed to throw the whole weight of the attack on the head of the French column and crush that before the rear, which would have been thrown out, could possibly come to its succor. The French, notwithstanding their superiority, as a whole, no doubt escaped an overwhelming defeat by getting under way and standing out to sea. The same plan of battle was carried out at the Nile. The head of the French column was doubled upon and crushed, while the rear was completely thrown out of action. What Nelson meant by writing to Duncan, after Camperdown, that he (Nelson) had profited by his (Duncan's) example, is not precisely clear. In the battle of Camperdown, October 12, 1797, Duncan made signal to form line; but, not waiting for all the ships to come up, he and his vice-admiral, Onslow, led down on the enemy in two irregular columns, not unlike the manner in which Nelson and Collingwood led the attack on the allied fleets off Trafalgar. In both cases the entire English fleet did not cut through the enemy's line, but some "brought to" to windward, thus placing the enemy between two fires.

Nelson, in his general order (dated on board the Victory off Cadiz, Oct. 18, 1805), divided the fleet into two lines, sixteen ships in each line, with an advanced squadron of eight of the fastest-sailing two-decked ships, which eight ships, added, if wanted, to either of the two lines (as the commander-in-chief might direct), would swell that line to twenty-four ships. Those eight ships constituted the reserve. Having made his general disposition, he adds—and here lies the gist of the whole matter—"The impression of the *whole British fleet* must be made (with the intention of overpowering it) on that *portion* of enemy's line rearward from the third or fourth ship ahead of its ler-in-chief presumed to be in the centre. I will suppose enemy's ships ahead untouched."* That is to say that, by

command of the fleet that was destined to operate against the rces of the enemy, Nelson summoned the admirals and captains of he cabin of the Victory. "When I came to explain to them my " he wrote to an intimate friend, "it was like an electric shock: rs; all approved. It was new, it was singular, it was simple, als downwards it was repeated, 'It must succeed, if ever they o get at them.'"

d said the plan of attack was irresistible.

doubling on the enemy's centre and rear, he threw the entire van out of action.* And yet, nearly a quarter of a century after Nelson's splendid illustration of a well-known principle of the science of war, we find two distinguished admirals of the British Navy telling us that the secret of their tactics is to "place ship against ship."

Leaving the sail period, let us now consider the state of Naval Tactics at the present day.

In an exhaustive article on the subject, which appeared a few years ago, the very able writer declared that, in the British Navy, Naval Tactics "*had not been so much neglected as despised.*" Just think of that! "*Not so much neglected as despised.*" He says: "In that service no tactical maxim has ever been held in so much honor as the simple phrase which asked only for a fair field and no favor."

"Plenty of sea room and a willing enemy," he continues, "was a formula which adequately expressed the aspirations of a body of men strong in their confidence of their superior seamanship and of their undoubted valor and endurance." Evidently, for such men, if such indeed there be in the English Navy, the lessons of Hawke and Nelson have been given in vain.

As late as 1872 there were a number of English writers who agreed in thinking that, notwithstanding their magnificent fleet of ironclads, they were still "no more than groping after something definite which it was hoped might arise at a future time." They had not yet a perfectly settled drill to guide them in their fleet evolutions.

Another author, writing about the same time, says: "The naval student is brought face to face with the great difficulty of modern Naval Tactics—the choice of weapons. What would be the English choice, should war come upon us now? It is somewhat painful to note that we have no choice. We vaguely hope that a wise choice

* It may not be out of place to call attention just here to the expression "breaking the enemy's line," so often met with in naval history. In Captain Montagu Burrows' "Life of Lord Hawke" the author says that "Lord Rodney was not the first to whom credit is due for '*breaking the enemy's line,*' an operation he put in practice with distinguished results in his famous battle of Dominica, and which after 1782 became the tactics of the British Navy."

Now, simply breaking the enemy's line amounts to very little in a tactical point of view, and may, if the opponents are fairly matched, be attended with evil results. But the author goes on, in tracing the development of fighting tactics, to explain that "the next step was to cut through the enemy's line and *double the force* on each ship so cut off. After the time of Nelson any other method seemed inconceivable."

will in some way be disclosed to us, and we do not take a great deal of trouble to see how things point. The position we hold is dangerous and improper." He continues: "While each of the four modern naval weapons, the gun, the ram, the Harvey torpedo, and the Whitehead torpedo, has its advocates, the great mass of naval men simply look on."

In the English Naval Prize Essay of 1879 the author says: "Evolutions are not tactics. Evolutions are simply fleet drill: the Signal Book is a drill book." He then proceeds to criticise the Signal Book, winding up with the remark: "Are there no broad principles which might be shadowed forth in the Signal Book? At present, it must be admitted, we are groping in the dark. Our evolutions and manœuvres have no direct bearing on battle formations. .... Modern naval warfare has so changed," he says, "and is in such a state of transition, that, failing a direct order from higher authority to deal with tactics, modern Signal-Book committees *have agreed to ignore them*, except so far as an occasional verbal change in an old signal might be adapted to modern warfare." Here, then, lies the whole trouble: the English have made no serious effort to get up a modern Code of Fighting Instructions. The essayist is not without words of praise, however, for the Signal Book, deficient as it is. "If," says he, "we turn to the definitions, we see a great improvement has taken place in recent editions, the terms 'guide of a fleet,' 'guide of a column,' and others, being comparatively new. The term 'column' is also new, and is now used to mean '*any number of ships in a distinct body, whether in line ahead, line abreast, or otherwise.*' The word," he adds, "has been objected to, with justice, as having a forced meaning, but at least it *describes clearly* a body of ships in any formation, and this was previously much required."

Further on he says: "Alluding to the old Signal Book" (and the new one, he tells us, is a mere transcript with a few extra notes and observations), "we ask if we are right in supposing that *all these signals, evolutions and manœuvres are intended as a groundwork for tactics? And, if so, where are the tactics?*"

Another writer asks the same question: "But are even the evolutions prescribed for the squadrons sufficient? *If battle is their object, where are their formations or plans of attack which they recommend?*" The former essayist answers the question himself by saying: "We have been living in peaceable times, and battle *and action*

*signals have been dropping out of the Signal Book. What remains?* Just ten articles of instructions for action which are mostly obsolete."

It must be admitted that these remarks of English Prize Essayists hold out small encouragement to hope for much instruction in tactics from the English Navy. And there is reason to believe that other navies are pretty much in the same unsettled state as to the best system of Steam Tactics, both Minor and Grand. Commander Hoff, who has taken great pains to gather together under one cover all that is latest and best of the published opinions on the subject, quoting from English, French, German, Italian, and Russian and Belgian writers, comes to the deliberate conclusion that "all of them are more or less unsatisfactory."

The conclusion forced upon us is inevitable—that we must begin *de novo* and build up this science for ourselves.

We might very well conclude here, but for one or two remarks of the distinguished officers just quoted which require a passing notice.

One writer says: "Evolutions are not tactics, though they may form the basis on which tactics are founded." And again, speaking of the Signal Book as a manual of drill in fleet evolutions, he asks, "Where are the tactics?" And again, another officer asks, in speaking of fleet evolutions in the Signal Book, "If battle be their object, where are their plans of attack?"

To these several remarks we may repeat that "Tactics is the Art of Military Movements." This applies to the movements of a fleet, or its evolutions. Hence, the evolutions laid down in the Signal Book do constitute, in themselves, what is known as Minor Tactics. Further, that the writers quoted have confounded two distinct branches, viz.: Minor or Elementary Tactics, which is limited to evolutions (see Introduction), and Grand Tactics, or the Tactics of Battle. This distinction is made by military writers, and it would be well for us to adopt it, here and now, for our Naval Terminology. We will thus avoid any confusion of ideas. In the English Navy they had for generations of flag officers the Fighting Instructions, and in France the Ordonnance du Roi, to both of which reference has been made. These comprised the Grand Tactics of the Sail Period. The great want now felt in both those navies are modern Fighting Instructions. That is what they are striving for. But, as we have said, and say again, nobody, to our knowledge, has arisen, so far, who has shown himself competent to draw them up.

Now, Elementary Tactics, or the system of fleet evolutions laid down in the Signal Book; Grand Tactics, or the manner of forming a fleet for battle, and for conducting it in battle, and Strategy, together constitute the science of naval warfare; and that is what we are now to study.

In starting out with a new study, it is not desirable to retain the terminology of an obsolete system. The English and French have both fallen into this error. The English still cling to the terms *line ahead, line abreast*, and *line of bearing;* while the French retain the terms used by Paul Hoste: *La Ligne de File, La Ligne de Front*, and *La Ligne de Relevement.* Now, strictly speaking, the term *line of bearing*, having reference to the wind, is inapplicable to steam tactics. It was a line six points from the direction of the wind, and a fleet was on the starboard, or larboard, line of bearing according as the ships composing it could fetch, by a simultaneous movement, into the line of battle on the starboard or larboard tack. The term is a convenient and expressive one, however, and having been adopted by writers on steam tactics, it should have a modified and precise definition given it.

Unhampered by traditions as we are, let us at once adopt the shorter, simpler, and equally expressive terms of *Line, Column* and *Echelon*, and their derivatives, to express the various formations of a fleet. We shall then avoid such clumsy expressions as *line ahead in single column*, and many similar ones common to writers of the day.

Our terminology should be precise, our definitions clear. Where old terms will answer, it is certainly well to retain them, even if the sense must be modified. But when we are actually wanting in terms, we may be safe in taking such as have passed into the currency of military literature.

Our attention, then, will be first directed to Elementary Tactics; next, to the Tactics of Battle, and lastly, to Strategy.

# U. S. NAVAL INSTITUTE, NORFOLK BRANCH.

FEBRUARY 2, 1887.

CAPTAIN GEORGE BROWN, U. S. N., *Vice-President*, in the Chair.

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## THE NAVAL STATION AT NORFOLK, VA.

BY LIEUTENANT R. M. G. BROWN, U. S. N.

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The vicinity of Norfolk possesses many great advantages for a dockyard, and it is a remarkable fact that not a single objection can be urged against making it the great shipbuilding yard now so urgently needed.

Just before the breaking out of the War of the Revolution the British Government established a naval station on the present site. This point was selected in preference to all others after a careful survey of all the ports in the North American dominions of Great Britain.

Sir George Collier captured Norfolk and the Navy Yard in 1779, but was ordered to abandon it, which he did under protest. In his letter protesting against the evacuation he said: "Permit me, as a sea officer, to observe that this port is an exceedingly safe and secure asylum for ships against an enemy, and is not to be forced even by great superiority."

During January, 1800, at the request of the President of the United States, the General Assembly of Virginia passed an act authorizing the sale of the property known at that time as Gosport to the United States, to be used as a permanent navy yard. It was accordingly sold to the United States for $12,000, there being sixteen acres in the property. The Yard was greatly increased in size about 1826 and 1827. It now contains eighty-two and one-half acres, and has a water front of 3860 feet, or about three-quarters of a mile. In 1834 the dry-dock, costing nearly a million of dollars, was completed. Saint Helena was added to the station in 1847, and the War Department turned over Fort Norfolk to the Navy in 1849. About 1878 and 1879 the main

powder magazine was moved down to Craney Island, and Fort Norfolk has since been used only as a temporary storehouse for powder.

In accordance with an act of the General Assembly, Governor Tazewell, in 1835, conveyed to the United States the jurisdiction over the new purchases, and also over the Fort Nelson property now used for the Naval Hospital. In these acts ceding property to the United States, the Commonwealth of Virginia reserved the right of executing any process whatever within the limits ceded, and also a provision was inserted that the property would revert to the Commonwealth of Virginia in case the Government of the United States ceased to use it for the purpose specified.

Captain Lull, U. S. N., in a short history of this Navy Yard, says: "No navy yard belonging to the United States, from its geographical position, is more important than that at Gosport, Va. Located near enough to the entrance of the Chesapeake Bay to be easily accessible, it is, at the same time, in a position readily defended from attacks either by land or by water, and one, as has been repeatedly shown, which can be held by a small force against a very largely superior one. There is in the vicinity an abundant supply of timber and other material, while the close proximity of a populous city secures to it the command of all the skilled labor that can be required.

"Such is the mildness of the climate that work of all sorts can be carried on at all seasons of the year without interruption. Hampton Roads, the outer harbor, is an excellent point of rendezvous for a fleet or squadron.

"A glance at the map will demonstrate the very great importance of a naval station in this vicinity. The Chesapeake, with its navigable tributaries, penetrates into the heart of several of the richest States in the Union, reaching to the national capital. A foothold in its waters would, therefore, be of the utmost strategic importance to an invading enemy, and would probably be one of the earliest objects sought by them, as past history has fully shown.

"The width of the entrance of the bay is so great that it would be impossible to defend it except by a naval force, which should have a repairing, coaling and victualing station as near at hand as possible, consistent with entire defensibility for itself, with a reasonably secure outer harbor, large enough for the necessary manœuvres of a squadron in getting under way and forming. All of these conditions are admirably filled by the location of the Gosport Yard."

The many changes in naval warfare in recent years have put the cities near deep water at a great disadvantage for defense against an enemy. The great range of modern ordnance enables a fleet to lie off a city like New York and destroy it without entering its harbor at all. Submarine mines, torpedoes, and rams can only be used with advantage when an enemy has to approach a city through narrow channels and rivers. They would all prove most effective in the defense of the Navy Yard at Norfolk. It is a great disadvantage to have a naval arsenal near a large and opulent city, the latter naturally inviting the attacks of an enemy, who thus has a double inducement to attempt the capture. The only advantage derived from having a navy yard near a large city is on account of the ability to óbtain skilled labor; but the lack of skilled labor has never been felt at Norfolk, nor will it be as long as the rents are so low and the markets so cheap. Besides, the laboring man has to incur but little expense for warm clothing in this climate. No more reliable laboring men can be found than in this vicinity.

So much has been said of the climate of Norfolk that it is unnecessary to speak of the great advantage possessed by this Navy Yard over all others on the coast in that respect. The great advantages in regard to coal, iron and lumber are also well known. The convenience of fresh water, where iron vessels can be preserved when not in commission, is also a great advantage that Norfolk possesses.

The Navy Yard can be extended very cheaply, if desirable. The plant can, at an expense of less than $100,000, be enlarged and improved so as to be equipped for building the iron ships required for the new Navy.

The stone dry-dock is an excellent one, but too small for the new ships. It is believed that Congress will at this session authorize the construction of a Simpson dry-dock,* located where the wet-dock is now, and large enough for any vessel of the Navy. This is much needed, and no labor or pains should be spared to obtain the necessary appropriation. As the South has but one navy yard in use, it would seem that Southern Senators and members of Congress should be appealed to and asked to support it. It is greatly to be regretted that an appeal is necessary under such circumstances.

An inexhaustible supply of the best fresh water can be obtained from Lake Drummond. It has long been known in the Navy by

* The construction of the dock in question has been authorized by act of Congress since the reading of this paper.—ED. COM.

the name of "juniper water," and has always had a high reputation for purity and healthfulness. There is great necessity for proper water-works connecting Lake Drummond with the Navy Yard, and it is clearly the duty of the Government to assist this undertaking, as it would insure the Navy Yard from fire much more efficiently than the expensive fire department now maintained. Besides, it would allow of proper sewerage and sanitary arrangements within the Navy Yard. Ships could also be furnished with fresh water at the dock, instead of by means of the expensive and unreliable method of water boats now in vogue. I understand that the Civil Engineer estimates the cost of laying the necessary mains and pipes throughout the entire Navy Yard at $17,000. Of course, an annual sum must be paid to the water company for supplying the water, but this has always been done at the other yards.

There is also a necessity for quarters for all officers attached to the Navy Yard. A like necessity exists for quarters for the officers and men of the Marine Corps. This should be constantly urged. It enables an officer to be near his post of duty both by day and night, and would do much to make the station a popular one, as it was previous to 1860.

A proper electric-light plant should be installed in the Yard, so that work could be carried on at night, if necessary, as well as by day.

It is true that much has recently been done to improve the condition of affairs. A much-needed fire-alarm system has been successfully inaugurated; a new and larger picket launch has been put in commission for the use of the officers and employes; a large tug has been fitted out and commissioned for Yard duty; an office has been built for the officer of the day; and many minor improvements have been made.

What seems to be one of the evils at present is want of concentration. It is too inconvenient to reach different points. The Franklin should, in my opinion, be moored alongside the Navy Yard wharf. A Herreshoff launch should be furnished the ordnance officer, so that he could easily inspect his different storehouses and magazines.

It would be an excellent thing if a street railway were built from the Navy Yard gate to the Norfolk ferry, and the ferry boats should run more frequently. This would enable Norfolk laborers more easily to reach the Navy Yard.

There seems to be no valid reason why the Hospital grounds should

not be converted into a public park; and the same can be said of the farm called Saint Helena, opposite the Yard, in the town of Berkley. Of course, care should be taken that the interests of the Government are properly protected.

In conclusion, I would say that while it is the interest and duty of a naval officer to point out the advantages of location, etc., of this Navy Yard, it is to the interest of Virginia and of the whole South that a demand for iron and steel be encouraged in a home port, in order that the expense of transportation may be reduced, and that the furnaces of the South may compete successfully with those of the North in furnishing steel for the new Navy.

## DISCUSSION.

Captain GEO. C. REMEY, U. S. N.—*Mr. Chairman and Gentlemen*:—Having regard solely to geographical location and site, I regard the Norfolk Navy Yard as the first in importance of all the navy yards belonging to the Government. Believing this to be so, I think it is the duty of the Virginia Representatives in Congress to urge and insist that ample appropriations be made to make the present Yard a first-class dockyard. To do this will require a comparatively large expenditure of money, but the day may come, and be not far distant, when such expenditure would be regarded as a wise one.

It seems to me, if the Virginia Representatives in Congress would endeavor to enlist all the Representatives in Congress from the South to advocate a modern dockyard, to be made of the present Yard, that appropriations looking to this might be secured if for no other argument than that this Yard is practically the only one in the South. Having this in view, it would be the duty of the Navy Department, and I do not doubt a pleasure, to elaborate plans so that all improvements made would be done systematically, looking to a modern dockyard as the result.

Regarding the facilities for obtaining iron and steel, it is evident from common report they will be produced and manufactured in large quantities in the States of Alabama, Georgia, and Virginia.

Statements have been lately made in the public press that iron and steel can be produced in Alabama cheaper than elsewhere in this country. Whether this now be so or not, it is evident to the careful observer that iron and steel are rapidly becoming most important interests in these States.

Surgeon GEORGE A. BRIGHT.—*Mr. Chairman and Gentlemen*:—As to the sanitary condition of the Norfolk Navy Yard, so far as it depends on local climatic causes, I may say that while there are a good many cases of malarial fever during the warm season, most of these cases have been light, and none of them really grave, during my experience of the latter half of 1886. I have seen no reason, then, to believe this station particularly unhealthy.

As to the water supply for the use of the houses and shops, for flushing sewers, and for use in case of fire, etc., the supply is unsatisfactory, depending upon the rainfall, and collected from the roofs of the various buildings in the Yard: it is stored in a reservoir under ground, whence it must be pumped for daily use. It is greatly to be desired that the Yard be connected with the proposed system of waterworks of Portsmouth.

The marine barracks of the Yard are disadvantageously placed in all respects. They are at the extreme south end of the station, remote from everything. The building is very plainly constructed, of wood, only one story high, and the floor is raised only a few feet above the soil. It is situated on damp ground, is insufficient in size, and insufficiently lighted. The closets are at a distance from the main building: they should be connected with the barrack by a covered way, as a protection in bad weather.

Assistant Naval Constructor BOWLES.—*Mr. Chairman and Gentlemen*:—An attempt to describe or set forth, even briefly, the necessities of this Yard in order to make it a busy, efficient and economical shipbuilding yard, requires careful consideration. The possibilities of this Yard are unsurpassed. Actually, at present, we have not the necessary furnaces, tools and appurtenances for building the smallest iron or steel ship. For a small sum—say not more than $50,000—tentative arrangements could be made in a short time which would enable us to build steel ships, but neither expeditiously nor economically. To accomplish these desirable objects, and to make this Yard what its climate, accessibility, location, readiness of supplies, and admirable natural advantages would justify, will require an entire redistribution of the shops and a large outlay in tools and plant.

I have previously suggested to the author of this paper the advantage of a careful study of the reorganization of the Yard by a board of officers, who shall digest and prepare a plan and estimates of cost to equip this Yard for building and repairing ships of all types.

In reference to the dry-dock, I have one point to submit for discussion—namely, it is now proposed to convert the timber dock into a dry-dock. It seems to me that it would be a better plan to remove the timber, renew and deepen the quay walls, and make it into a fitting-basin, with shears, cranes, etc., for fitting engines and boilers, armor, guns, etc. The timber dock is at present surrounded by buildings available for shops.

Again, it is an advantage and economy in many ways to have the dry-docks near together. One set of pumping engines would answer for both, the character of the work at the docks is similar, the implements and accessories in docking and undocking are common. In my opinion, it would be very inconvenient to build another dry-dock so far from the present one as the timber dock. In active shipbuilding the necessity of a fitting-basin free from the effect of tidal currents and the movements of vessels in the stream would be greatly felt.

Among the disadvantages of the present arrangements in the Navy Yard are the location of the offices and the wide distribution of the shops, the lack of any means of communication. A telephone system would be found indispensable in busy times.

I would ask, also, Mr. Chairman, if it be not true that, of all our navy yards, Norfolk has the most convenient and abundant facilities for the supply of an excellent quality of semi-bituminous coal, for which all our new vessels are designed.

THE CHAIRMAN.—*Gentlemen* :—The Department recognizes the importance of introducing water in the Yard, and the Chief of Bureau of Yards and Docks has asked for an appropriation for the purpose of laying water mains, putting in hydrants, etc., and connecting the system with the 8-inch main of the Portsmouth Water Company which runs to the main entrance gate. We would then not only have an ample supply of water for fire and other purposes, but there would be much less loss of time than now exists by the employes going to the water front.

Long before Norfolk or Portsmouth had any railroad connections with the interior this station was regarded as second to none as a rendezvous for our ships for obtaining needed supplies. How much more important it now is can be readily seen, more especially as a coaling station. The modern ships are designed to burn bituminous coal, and we now have two railroads connecting with coal-fields, and coal can be brought by rail to St. Helena direct from the celebrated mines where we get the "Pocahontas steam coal," than which none superior for steaming purposes is found in the United States.

Should this become an active shipbuilding Yard, many changes would have to be made in the location of offices, as the heads of departments should have their offices near the shops of which they have charge. Then, with a local telephone system in the Yard, the commandant could communicate with the officers without loss of time.

The necessity for a marine barracks at this station has long been recognized by every one except the Appropriation Committees of Congress. The efficiency of the guard is not promoted by the discomfort to which the men are now subjected.

As is now well known, the South is advancing rapidly in the development of its iron and steel industries, but the Southern steel manufactures cannot at present compete with those of Pennsylvania on account of the distance the steel has to be transported in order to reach a shipbuilding establishment. A shipbuilding establishment at Norfolk actively engaged in building iron and steel ships would remedy this evil and put the two sections on a more equal footing.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

# ECONOMY OF COMPOUND DIRECT-ACTING PUMPING ENGINES.

By Passed-Assistant Engineer C. R. ROELKER, U. S. N.

The following account gives a description and record of tests made by the writer in the early part of 1886 on the new compound pumping engine then recently erected by the Blake Steam-Pump Company at the Kings County Oil Works, Greenpoint, L. I. These tests were made with the view of ascertaining the economy to be gained by the use of compound instead of simple engines for direct-acting pumps.

## DESCRIPTION OF THE PUMPING ENGINES.

The pump draws the water from Newtown Creek, through a suction pipe 16 inches in diameter and 222 feet 4 inches long, and delivers it into a large main 14 inches in diameter, whence it is distributed, through branch pipes varying in diameter from 8 to 12 inches, to the cooling coils of the oil refinery and for other purposes. The aggregate length of the main and branch discharge pipes is 1572 feet. The height to which the water has to be raised on the suction side varies with the tides; the water is delivered ordinarily against a head of about 35 feet.

The pumping engine consists of a horizontal double-acting pump, actuated directly by a compound steam engine having one (1) H.-P. and one (1) L.-P. cylinder. The H.-P. cylinder is secured directly to the inner head of the L.-P. cylinder and, by means of four (4) stay rods, to the pump cylinder; the axes of the three cylinders lying in the same straight line. The piston rods of the pump and of the two steam cylinders are secured to a common cross-head. The pump is of the well-known Blake pattern, and has air vessels of ample capacity fitted to the suction as well as to the discharge side.

The valve gear of the steam cylinders contains the latest improvements made by the Blake Steam-Pump Company. The slide valves of the H.-P. and L.-P. cylinders are coupled together and worked jointly by an auxiliary steam cylinder located above the valve chest of the H.-P. cylinder. The piston rod of the auxiliary steam cylinder and the main valve rod are coupled to a lever the arms of which are so proportioned as to give the proper travel of the slide valves for the full stroke of the piston. An auxiliary slide valve, operated by means of a tappet and lever from the main cross-head, regulates the movements of the auxiliary piston. The exhaust of the auxiliary cylinder is led to the condenser. The L.-P. cylinder is provided with an adjustable cushion valve at each end, by means of which the length of stroke of the engine can be regulated to a great nicety.

The H.-P. cylinder exhausts into a receiver, which is a separate vessel located under the H.-P. cylinder and having a capacity equal to about 2.17 times that of the H.-P. cylinder. The receiver is considered essential to the smooth and regular working of the direct-acting pumping engine, as it prevents the shock resulting from the immediate impact of the high-pressure steam discharged from the H.-P. cylinder into the L.-P. cylinder. It also serves as a "separator," furnishing dryer steam to the L.-P. cylinder. Both cylinders are thoroughly steam-jacketed at the ends as well as at the sides: the steam for the jackets being taken from the main steam pipe. The drain pipes of the jackets and of the receiver are connected with automatic steam traps. The cylinders and receiver are covered with a thick layer of hair-felt and completely lagged.

The exhaust of the L.-P. cylinder passes ordinarily into a cone jet condenser, the condensing water being taken from the discharge of the pumping engine, and a small Blake steam pump serving as an air pump. During these tests, however, a "Wheeler surface condenser" was used instead of the cone jet condenser. The steam cylinder of the air pump exhausted into the atmosphere during the trials.

### PRINCIPAL DIMENSIONS OF THE PUMPING ENGINE.

Diameter of pump cylinder, 24 inches; diameter of H.-P. cylinder, 12 inches; diameter of L.-P. cylinder, 24 inches; nominal length of stroke of pistons, 24 inches; extreme length of stroke of pistons, including clearances, 25 inches; diameter of pump piston rod, one (1), 2½ inches: diameter of H.-P. piston rod, one (1), 1¾ inches;

diameter of L.-P. piston rods, two (2), $1\frac{3}{4}$ inches; valve ports of H.-P. cylinder, single, $1\frac{1}{8} \times 6$ inches; valve ports of L.-P. cylinder, double, $1\frac{1}{8} \times 12$ inches; travel of valves, $2\frac{1}{4}$ inches; diameter of auxiliary steam cylinder, 4 inches; stroke of piston of auxiliary steam cylinder, 8 inches; extreme width of pumping engine, 3 feet 1 inch; extreme length of pumping engine over bolts of cylinder flanges, 13 feet $7\frac{5}{8}$ inches; extreme height of pumping engine, exclusive of air chamber, 5 feet $8\frac{5}{8}$ inches.

All the working parts of the pumping engine are made of the best material, finished and fitted in a substantial and workmanship-like manner. It works with great smoothness and regularity. The extreme differences of stroke observed during all the experiments did not exceed $\frac{5}{8}$ inch. The nominal length of stroke was always exceeded, and the regulating valves acted with such nicety that the pistons were never observed to strike the cylinder heads, although they traveled the extreme length of the stroke. The pump is working continuously night and day, and is reported as giving complete satisfaction to the owners.

### Manner of Making the Tests.

The tests took place on January 21 and February 13, 1886. The conditions of each trial were maintained as uniform as possible. The steam stop-valve of the engine was set for a certain speed of the pump at the beginning of each test, and remained unchanged during its course. The pressure in the water main and the speed of the engine were maintained as nearly uniform as the proper working of the plant permitted. No sudden fluctuations or changes of speed or pressure ever took place.

The test of January 21st continued for four hours. The engine was worked compound, all the steam jackets being in use. The piston speed of the engine during this trial was greater than that at which it works under ordinary conditions.

On February 13th the engine was run for one hour as a compound engine, with the steam jackets in use, but the piston speed and power developed were less than during the previous trial, being such as obtain in the ordinary working of this engine.

After the completion of this trial the engine was worked for two hours non-compound by admitting steam to both sides of the H.-P. piston continuously through the indicator pipes and cocks. Indicator cards taken from the H.-P. cylinder under these conditions showed that the fluctuations of pressure during the stroke were very small.

The piston speed and power developed were nearly the same as during the immediately preceding trial, but the steam was shut off from all the jackets.

Complete sets of indicator cards were taken at frequent regular intervals simultaneously from the water cylinder and both steam cylinders by three observers. The same indicators were used during all the trials, and the correctness of their scales was ascertained by comparison with a standard.

Readings of the steam, vacuum and water-pressure gauges, thermometers and counter, were likewise taken at frequent regular intervals and recorded in the log.

The exact length of the stroke was recorded, by a pencil attached to the cross-head, on a strip of paper.

The weight of steam consumed by the engine was ascertained by weighing all the water discharged by the air pump on carefully adjusted platform scales.

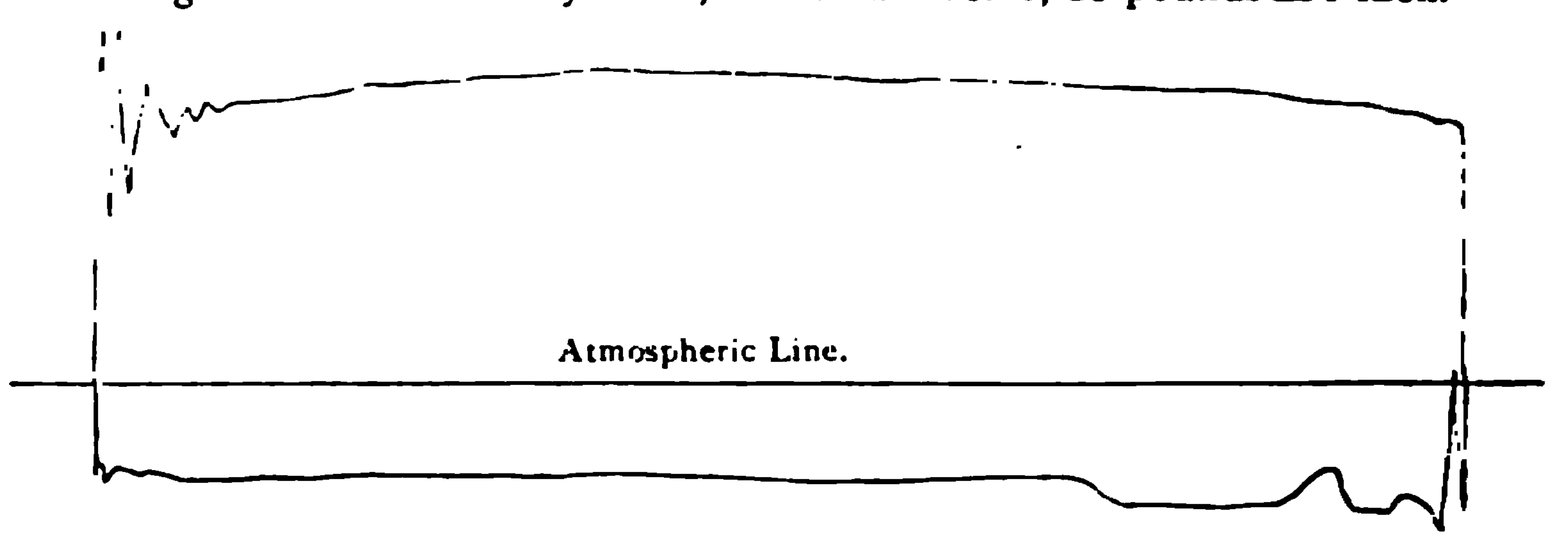
The weight of steam condensed in the jackets and receiver and discharged through the traps could not be observed in the course of the tests. The superintendent of the oil works, Mr. J. W. Van Dyke, had these quantities measured subsequently on two different occasions, for periods of four hours and two hours, while the pumping engine was working under normal conditions, and has kindly furnished the results to the writer.

The indicator cards hereto appended represent average conditions of the two trials of February 13, 1886:

FEBRUARY 13, 1886. CARD NO. 2. 11.55 A. M.

Single strokes per minute, 36.4; steam gauge, 60 pounds; vacuum gauge, $23\frac{7}{8}$ inches; M. E. P., both ends = 26.05 pounds.

Diagram from Water Cylinder, one end. Scale, 20 pounds = 1 inch.



FEBRUARY 13, 1886. CARD NO. 2. 11.55 A. M.

Single strokes per minute, 36.4; steam gauge, 60 pounds; vacuum gauge, 23⅞ inches; M. E. P., both ends = 43.18 pounds.

Diagram from H. P. Cylinder, one end. Scale, 31 pounds = 1 inch.

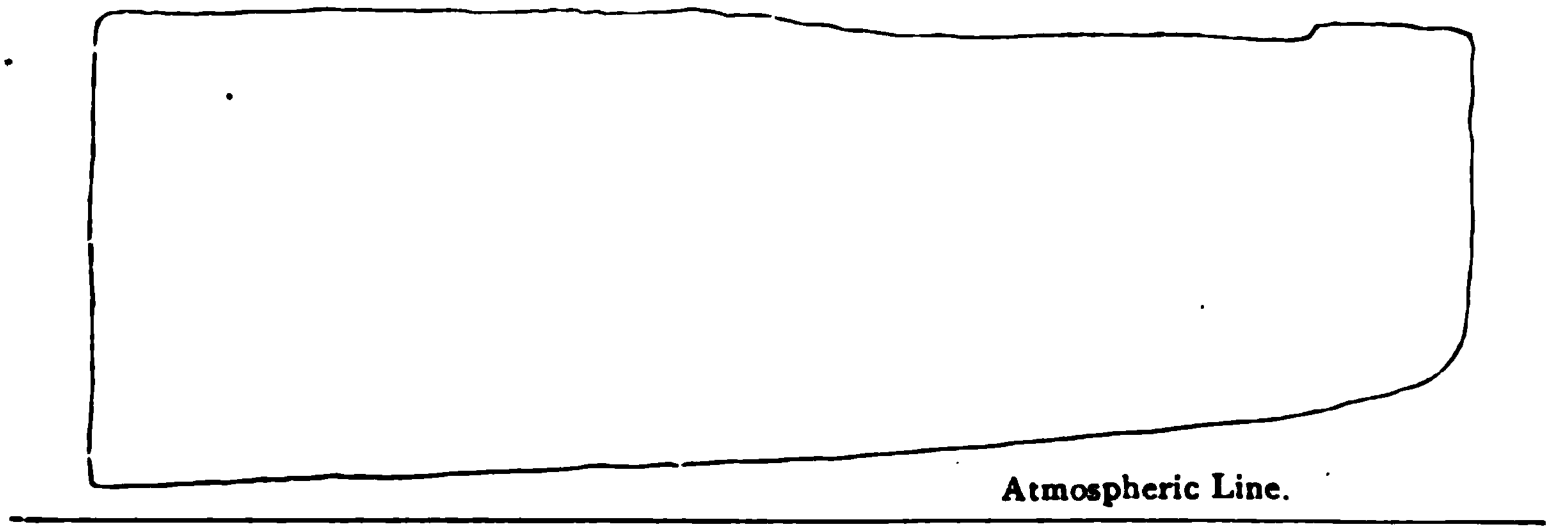
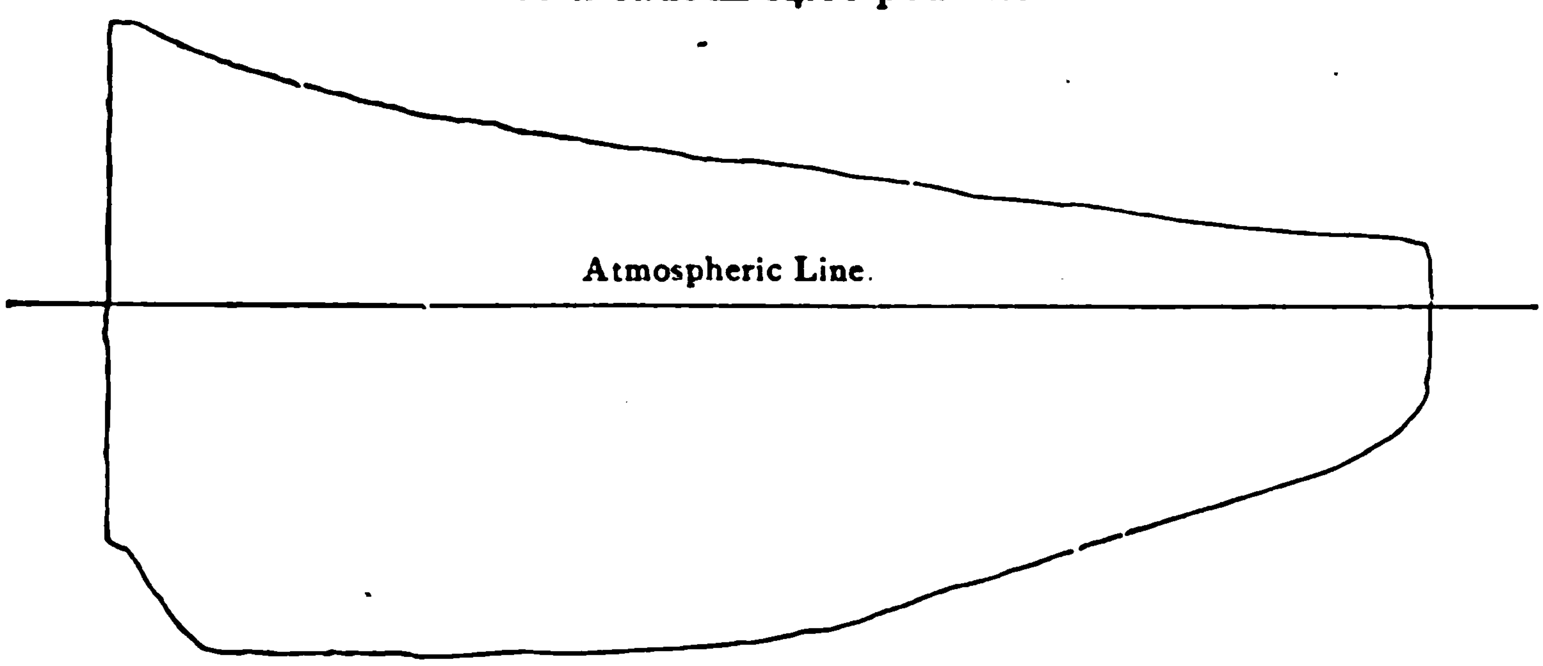


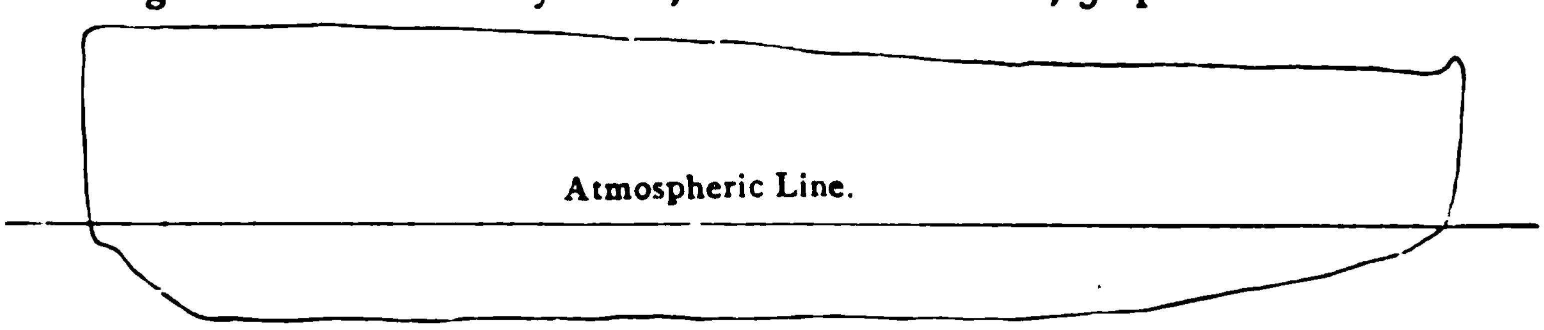

Diagram from L. P. Cylinder, one end. Scale, 9.8 pounds = 1 inch; M. E. P., both ends = 14.16 pounds.




FEBRUARY 13, 1886. CARD NO. 8. 3 P. M.

Single strokes per minute, 31.29; steam gauge, 57 pounds; vacuum gauge, 21.5 inches; M. E. P., both ends = 26.58 pounds.

Diagram from Steam Cylinder, both ends. Scale, 31 pounds = 1 inch.



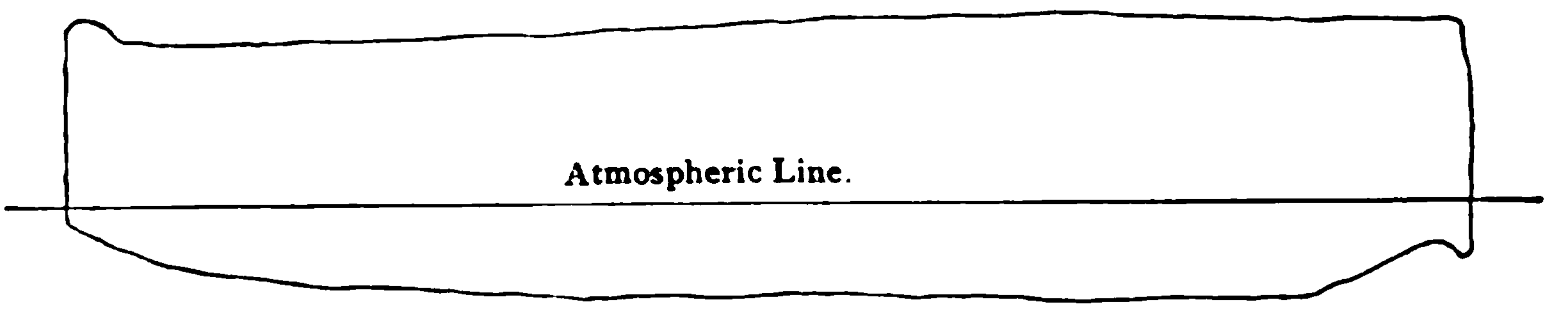
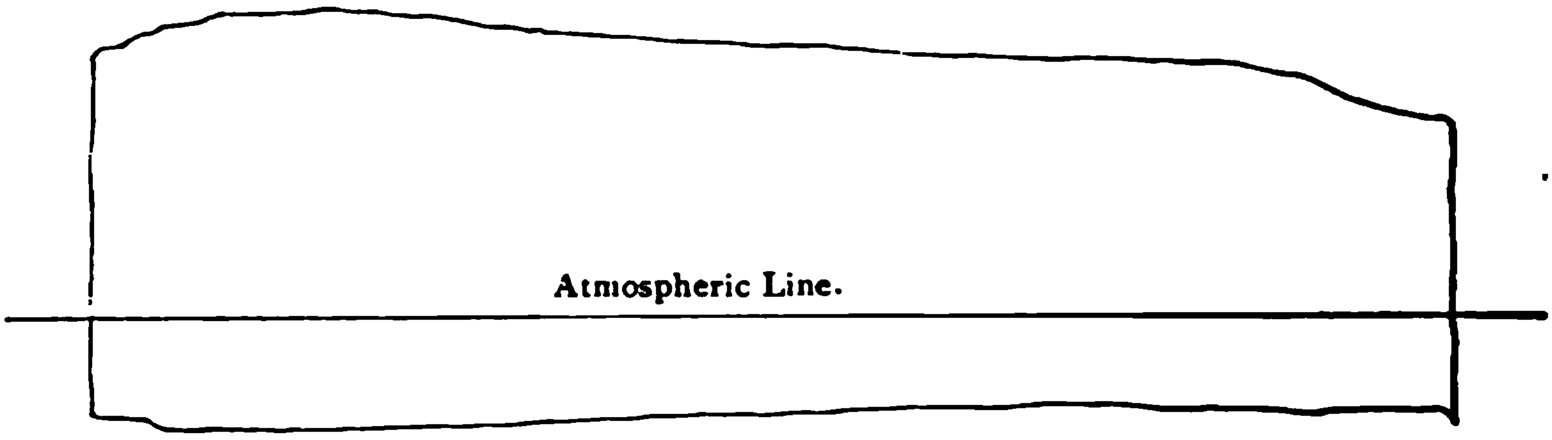
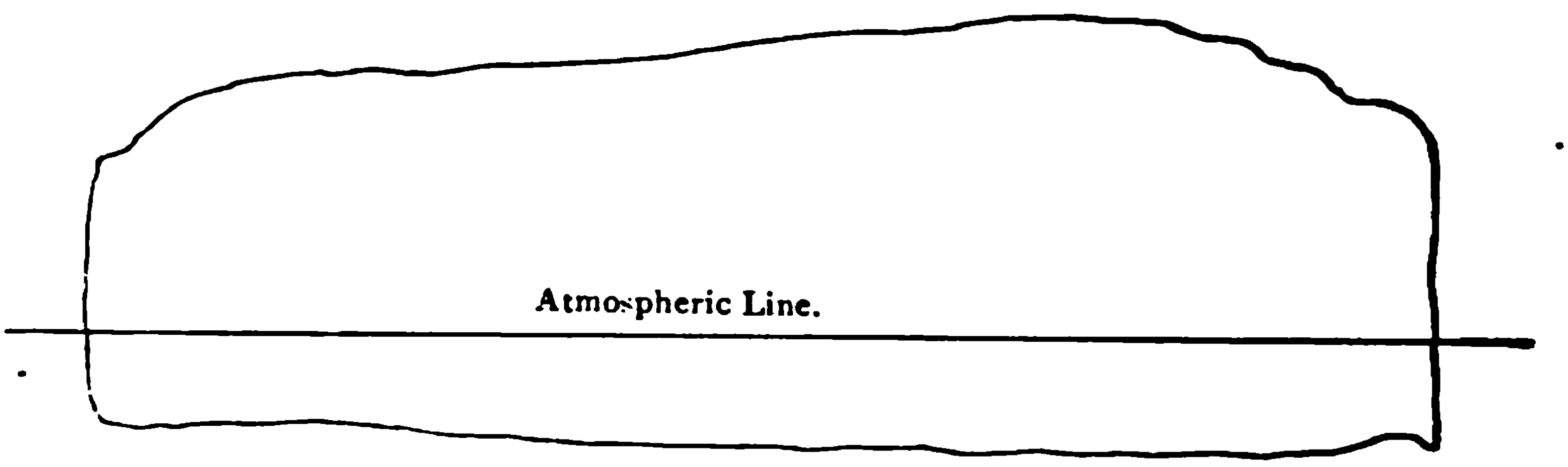



Diagram from Water Cylinder, both ends. Scale, 20 pounds = 1 inch; M. E. P., both ends = 24.483 pounds.




## RESULTS OF TESTS.

| | | | |
|---|---|---|---|
| 1. Date of test | Jan. 21, 1886. | Feb. 13, 1886. I. | Feb. 13, 1886. II. |
| 2. Duration of test in hours and minutes | 4 h. | 58½ m. | 2 h. |
| 3. Steam pressure by gauge, pounds per square inch above atmosphere | 58 | 61 | 56.375 |
| 4. Vacuum in condenser by gauge, ins. of mercury | 24.5 | 23.8 | 21.67 |
| 5. Vacuum in suction pipe of pump by gauge, ins. of mercury | 12.04 | 10.25 | 10.25 |
| 6. Pressure in discharge chamber of pump by gauge in pounds per square inch above atmosphere | 14.61 | 16.88 | 14.53 |
| 7. Single strokes of pump per minute | 54.9166 | 34.94 | 31.866 |
| 8. Length of stroke, inches | 24.6987 | 24.75 | 24.875 |
| 9. Piston speed in feet per minute | 112.997 | 72.06 | 66.047 |
| 10. Temperature of injection in degrees Fahr. | 32° | 32° | 32° |
| 11. " " discharge " " | 54.96° | 80.2° | 81.35° |
| 12. Temperature of hot-well in degrees Fahr. | 116.85° | 132.5° | 140.5° |
| 13. " atmosphere " " | 71 | ... | ... |
| 14. Barometer, inches of mercury | 29.98 | ... | ... |
| 15. Initial steam pressure in H.-P. cyl. above atm. | 55.154 | 51.54 | ... |
| 16. Final " " " " " | 54.96 | 52.41 | ... |
| 17. Mean indicated steam pressure in H.-P. cyl. | 42.7347 | 43.19 | ... |

| | | | |
|---|---|---|---|
| 18. Initial steam pressure in L.-P. cyl. above atm. | 11.746 | 8.82 | 19.38 |
| 19. Final " " " " ... | 5.8 | 2.6 | 18.5 |
| 20. Mean indicated steam pressure in L.-P. cyl.... | 16.589 | 14.21 | 26.97 |
| 21. I. H. P. developed in H.-P. cylinder............ | 16.4355 | 10.58 | —.25 |
| 22. " " in L.-P. " ............ | 25.6027 | 13.89 | 24.29 |
| 23. " " in both steam cylinders.... | 42.0382 | 24.479 | 24.04 |
| 24. " " in pump cylinder............ | 41.3695 | ... | 22.46 |
| 25. Total weight of water delivered by air pump during the test, pounds.................................. | 4832 | 671.5 | 2885 |
| 26. Weight of water delivered by air pump for one hour, pounds.................................. | 1208 | 688.7 | 1442.5 |
| 27. Weight of condensed steam discharged from jackets and receiver per hour according to test made January 27, 1886.............................. | 139 | 88 | ... |
| 28. Sum of two preceding quantities, being total weight of steam consumed in pumping engine per hour.............................................. | 1347 | 776.7 | 1442.5 |
| 29. Weight of steam consumed per I. H. P. of pumping engine, pounds per hour.................. | 32.4 | 31.3 | 60 |
| 30. Weight of steam in H.-P. cylinder at end of stroke in pounds per hour as shown by indicator. | 913 | 564 | ... |
| 31. Preceding quantity expressed in percentum of total weight of water delivered by air pump...... | 75.58 | 83.35 | ... |
| 32. Weight of steam in L. P. cylinder at end of stroke in pounds per hour, as shown by indicator. | 1133 | 612 | 1032.9 |
| 33. Preceding quantity expressed in percentum of total weight of water delivered by air pump...... | 93.79 | 88.86 | 71.65 |

## Explanation and Discussion of Results.

Lines 3 to 14 of the preceding table contain the means of all the quantities recorded in the log for each trial. The steam gauge was attached to the steam pipe, close to the engine. The spring gauge connected with the pump-discharge (line 6) was located four feet higher than the indicator attached to the pump.

Lines 15 to 24 contain the means of the quantities computed from all the indicator cards taken during each trial. The indicated horse-power on lines 21, 22, and 23 is computed from the mean piston speeds (line 9), and the mean indicated pressures of all the cards taken during each trial (lines 17 and 20).

The quantity on line 21 for Trial II. of February 13—viz. —.25, represents the work done in overcoming the resistance of the steam in the H.-P. cylinder in passing from one side of the piston to the other side through the indicator pipe; this pipe, half inch in diameter, was

too small to make this resistance inappreciable. A number of cards were taken to determine this resistance.

The indicated horse-power (line 24) of the pump was computed from the mean indicated pressures of all the cards and the mean piston speed given on line 9. The cards taken from the pump cylinder during Trial I. of February 13 were rejected on account of discrepancies.

It should be remembered that the indicated horse-power of the steam cylinders (line 23) does not include the power required to work the valve gear, this being done by the auxiliary steam cylinder. The absence of all journal and cross-head-guide friction contributes to make the net effective power of these direct-acting pumping engines a large percentum of the indicated power of the steam cylinders.

The quantities on line 29 are computed for the indicated horse-power recorded on line 23, which does not include the power required to work the slide valves and gear, while the quantities on lines 25, 26 and 28 include the weight of steam expended in the auxiliary cylinder. This insignificant error does not affect the comparison of economic efficiency of the compound and non-compound engine.

Line 29 shows that the weight of steam consumed per indicated horse-power of the pumping engine, when worked compound with steam jackets in use, was 53 per cent. of the weight of steam consumed when it was worked non-compound and without steam-jacketing. A comparison of the quantities on line 33 proves that the steam-jacketing was very effective in reducing the cylinder condensation, and it contributed undoubtedly no small share to the economic efficiency of the pumping engine. It should, however, be stated that the L.-P. cylinder was larger than the steam cylinder of a non-compound pumping engine properly proportioned to the work to be done would have been. On this account the economic gain due to working the engine compound, as shown by the experimental results, is somewhat too great.

According to calorimetric tests made on January 27, 1886, the percentum of moisture contained in the steam supplied to the engine was 2.917 percentum.

The results of these tests are applicable to the pumping engines of the U. S. Ships Dolphin and Chicago, which were built by the Blake Steam-Pump Company, and resemble in type and proportions closely the experimental engine. These pumping engines have one zontal steam cylinder, 22 inches diameter by 24 inches stroke,

and one (1) horizontal double-acting circulating pump, 26 inches diameter by 24 inches stroke. The axes of the steam cylinder and pump lie in the same straight line, and the piston rods of cylinder and pump are secured to a common cross-head, from which the two vertical, single-acting air pumps are worked by means of a link and a double bell-crank lever. The steam cylinder is not steam-jacketed, but covered with hair-felt and wood lagging. A full description and illustrations of these pumps will be found in the *Mechanical Engineer* of September 19, 1885, where a thorough analysis of the excellent performance of these pumps during the several trials of the U. S. S. Dolphin is given.

The substitution of compound cylinders for a simple steam cylinder in the pumping engines of the Dolphin and Chicago would increase their weight about 1200 pounds—an insignificant amount, considering that this same weight represents the saving in fuel, for 36 hours' steaming, to be gained by compounding the engine.

A more serious consideration is the additional space occupied by the compound pumping engine—viz. 2 feet 3 inches in the direction of its length. But the saving in fuel must be considered as overbalancing greatly also this objection.

The largest dry-dock on this continent is the timber dry-dock built by the Simpsons at St. John's, Newfoundland, for the Colonial Government. It is one that will accommodate any merchant vessel now afloat except the Great Eastern. Its dimensions are: Greatest length on coping (head to outer gate-sill), 610 feet 10 inches; greatest width of body on coping, 132 feet 6 inches; least width of entrance on coping, 84 feet 9 inches; length on keel-blocking, 563 feet, and greatest draught of water over sill, 25 feet. This dock is similar in shape and construction, in general details, to the other large wooden graving-docks of later construction in the United States, and a description of its construction will answer for all.

A coffer-dam was first built outside the proposed work; the excavation was then made after the enclosed site (which was only partially bare at low water) had been pumped dry. The foundation of the dock consists of wooden (spruce) piles, excepting the floor in this particular dock, which rests upon a bed of Portland-cement concrete varying from 2½ to 6 feet in thickness, which in turn rests upon a compacted, slaty gravel immediately overlying the bed-rock. Iron tubes were inserted in the gravel along the floor in a vertical position on each side near the axis of the dock and built in the concrete, with their upper ends left exposed above the surface, in order to drain any water that should happen to be in the substratum. Longitudinal timbers of yellow pine about 3 feet apart were imbedded in the concrete floor-foundation and anchored to it by iron bars and bolts. Upon these were laid floor timbers, which are covered in turn by spruce planking to form the working floor. Keel-blocks and sliding bilge-blocks are secured to the floor timbers. Provision was made also for open drains on each side of the keel-way under the floor timbers leading to the pump-well at the lower end.

The sides and head of the dock are built on a slope of 54° outward from the vertical. Six rows of piles were driven around the sides and head. Upon these piles are supported inclined heavy brace timbers of yellow pine running from the bottom of the dock to the top, and abutting upon the floor timbers at the lower end. These timbers form the skeleton, as it were, of the dock. At the upper ends these brace timbers are secured to a system of cross-caps or stringers 2 feet beneath the surface, extending back 30 feet from the coping, and supported by six rows of piles, to which the caps are firmly secured. This prevents spreading. Diagonal timbers are also introduced to tie these two systems of braces, cross-caps, and piles together. The

altars or steps of the dock are sawn out of square timber, a diagonal cut making two altars, the cut side being secured to the inclined brace timbers forming the skeleton of the dock; these altars when thus bolted forming a broad stair or treadway the entire length of the docks on both sides, by which the floor of the dock is readily reached from any point on the coping. The space behind the altars, as the sides are built up, is carefully filled in with clay from the excavation, and the filling well compacted by ramming. Around the entire dock and immediately outside of the outer row of piles supporting the cross-cap timbers a line of 5-inch tongued and grooved spruce sheet piling is driven to exclude the passage of tide-water.

The gate sills are of oak, the entrance being of timber sides sloping about 30°; the sides and floor of the entrance being built of solid yellow pine timber in two thicknesses, laid to break joints and filled in behind and underneath with concrete. To the outside faces of the sill are secured rubber gaskets, by means of which the gate joint is made water-tight. No groove is necessary for the iron caisson or floating gate, which is of the usual type, it bearing directly against the sill and solid timber of the abutment, being kept in place by the pressure of the water outside, and the joints water-tight by the rubber gasket.

The dock is filled by eight sluice-gates in the caisson, controlled by suitable valves and emptied in the usual way by steam pumps.

This dock, the largest in America, was constructed and opened for use within nineteen months from the date of commencement. Its cost was $550,000. It is but fair to state that the site was a favorable one for excavation, and that special privileges for importing machinery, etc., free of duty were granted to the contractors.

The Erie Basin dry-docks, two in number, one of them the largest on the Atlantic coast of the United States, have some points of difference from the St. John's dock. The principal point of difference is that the sides from high-water level to the top of coping are built of concrete in a monolithic form, faced with a patent artificial stone; this includes the five upper altars. This space is that most exposed to decay, and which first requires repair.

To show the rapidity with which this dock may be constructed, the dock built for the Cramps at Philadelphia may be instanced. This is 450 feet in length over all, cost $300,000, and was built in nine months.

The granite and concrete dry-dock at the Navy Yard, Mare Island,

has cost to date, in round numbers, $2,500,000, and has been in course of construction for twelve years. It is now in condition for use, but it is estimated that it will take $150,000 in money and one year in time to finish the facing and the surroundings. It is but just to say that irregular appropriations and day's work are, to some extent, responsible for this, but those obstacles and increased expenditures are just such ones as will be likely to be met with again in a similar case.

For this sum of money three timber dry-docks of the same size could be built by contract in two years, the timber dry-docks having all the advantages of stone excavated docks excepting permanence, and with the following points of superiority confidently claimed:

1st. That they are dryer and consequently more comfortable and healthy for the workmen.

2d. That wooden docks are cooler in summer and warmer in winter than those of stone.

3d. That the facilities afforded workmen by the low and narrow altars are superior to those of existing stone docks, and that the form of the altars avoids all cutting of shores.

4th. That the annual cost of repairs is less than for a stone dock in a northern climate.

5th. That even if the timber face of the dock should decay and require renewal every twenty years, the interest on the saving in first cost would be much more than sufficient to meet this contingency.

6th. That a wooden dock by contract can be built at a cost of one-half to one-third that of a stone structure of similar size.

As an example of the cost of repairs, the Boston dry-docks have been quoted before; and as improvements have been made in the construction of these docks, it may be fair to state that the largest and last built, No. 1, in 1864, was reported in 1886 by its owners to have cost but $5000 for repairs since its completion. I may add that there is no danger of the teredo injuring the dock inside, as all sea-worms require a constant supply of salt water to keep them alive, and the outside entrance-walls should be made of stone or concrete. As an extreme case of the repairs to a stone dry-dock, I will quote the case of the New York dock, which will be closed for several months and have repairs made to it at an expenditure of $100,000.

In closing this brief description of the Simpson system of docks and their advantages, it is considered not out of place to quote the following from the last annual report of the Chief of Bureau of Yards and Docks, who is to be congratulated upon his success in adding to the docking facilities of the naval service:

"Our own experience, as well as that of all other naval and maritime countries, places beyond reasonable dispute the superiority of excavated dry-docks over any other means of docking, and the greater cost and length of time formerly required in building these docks have been very materially reduced in the wooden dry-docks on the Simpson plan, which have been successfully in use in several ports on the Atlantic coast for a number of years.

I would submit, as a matter for your consideration, the question of the advisability of providing dry-docks at comparatively remote places which are frequented by merchant shipping, for the use of the Navy in combination with the merchant marine.

Such places as Puget Sound, in the extreme Northwest, and Pensacola, on the Gulf of Mexico, would be cases in point where timber for wooden dry-docks abounds and where no facilities for docking exist.

In addition, these docks would add greatly to the resources and facilities for the naval defense of these waters in time of war. At present there are no large dry-docks in the United States nearer Pensacola than Norfolk, Va., and nearer Puget Sound than San Francisco. The means for accomplishing this can readily be effected either by the construction and maintenance of these docks by this Department, charging moderate dues for docking merchant vessels, or by assisting private parties by advance of money or grants of land, with the conditions that Government vessels be docked free of cost forever, and that the United States have control in time of war or of certain emergencies.

A precedent for the latter plan has already been established in other countries, and recently in the United States by the grant of Government land in Baltimore to a dry-dock company upon the condition that all Government vessels be docked free of charge."

U. S. NAVAL INSTITUTE, NEWPORT BRANCH.

FEBRUARY, 1887.

# NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

## No. XIII.

It is admitted that among the methods proposed for the estimation of the nitrogen contents of nitrates or nitric esters, the speediest and most accurate is that which is based upon Crum's reaction, *i. e.* by shaking with an excess of sulphuric acid and mercury and measuring the nitrogen oxides evolved. It will be generally admitted also that the most convenient and accurate means of applying this method, especially for fluids, or for substances easily soluble in water, is found in the nitrometer described by Lunge.† This instrument is now generally made use of for testing nitroglycerine in the factories, and likewise for the analysis of the various kinds of dynamite.

For the direct analysis of explosives which contain nitroglycerine mixed with other bodies, such as nitrocellulose and the like, other means were considered necessary, for the bodies could not be dissolved, and so gotten into the nitrometer. In order to use the Crum reaction with these bodies, W. Hempel ‡ constructed another form of nitrometer. Hampe,§ in an extended discussion of nitrometric methods, pronounces the Hempel method convenient, easily performed, and very exact for all bodies which evolve nitrogen oxide

* As it is proposed to continue these Notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications or trade circulars. Address Torpedo Station, Newport, R. I.

† Ding. Poly. Jour. **228**, 447, 1878 ; **231**, 522, 1879; **243**, 421, 1882 ; **258**, 361, 1885.

‡ Zeitschrift für Anal. Chem. 82 ; 1881.

§ Ueber die Analyse der Sprengkörper, 18 ; 1883.

exclusively. Partly in order to be able to analyze bodies containing carbon dioxide, and partly on account of the expensiveness of Hempel's instrument, Hampe devised another method, which depends upon the fact that the nitrogen oxide evolved by the Crum reaction is converted into nitric acid by means of oxygen and hydrogen dioxide, and that this acid is then nitrated with a normal soda solution, thus following the analogous method of Schloesing for the estimation of nitrogen by ferrous chloride, which is now almost entirely abandoned for the gasometric method. The Hampe method does not appear to be employed to any extent—Lunge not having found it in use in a single factory visited—probably on account of its indirectness. When, as is often the case with a new dynamite, it is necessary, for complete analysis, to separate the soluble inorganic nitrates from the esters (nitrocellulose and nitroglycerine) by extraction, then the Lunge method is still the simplest and most convenient. Only in direct analyses of guhr-dynamites and pyroxylins has it appeared that the Hempel, or perhaps the Hampe, method was to be preferred.

A recent discussion of these methods has been published by Lubarsch,* who disputes the assertion that Hempel's nitrometer is convenient and easy of use; on the contrary, to attain correct results with it requires unremitting necessity for the quickest possible work in the introduction of the substance into the evolution chamber, while great skill and experience are required in filling the latter with mercury. Its use also includes no less than three sources of error—viz.: loss of material during solution; loss of nitrogen oxide while charging the vessels, and finally loss from the air-bubbles unavoidably present. For porous gun-cotton especially the process is hardly feasible. For explosives containing carbonic acid it is unsuitable in principle. Lubarsch considers Hampe's method too indirect for practical use. On this account he has devised an instrument which he calls a "reversion nitrometer." Lunge urges that this instrument is a step backward, as mercury must be added or withdrawn from the apparatus to get the desired quantity; the diameters of the two tubes are unlike, and hence the meniscus depressions are unequal; the use of a carbon-dioxide generator is onerous, and the neutralization of the lime in the gun-cotton unlikely to take place uniformly; while the cost of the instrument is 50 M., as against 13 M. for Lunge's.

Lunge has now made an addition to his nitrometer by which he claims to have secured all the advantages of Hempel's and Lubarsch's

* Programm des Friedrich's-Realgymnasiums, Gartner's Verlag, Berlin, 1885.

instruments at almost no expense, while maintaining the superiority for simplicity and readiness of use which his instrument has heretofore possessed. This addition consists of a thistle tube, whose stem is bent twice and then inserted in a rubber cork, which fits the funnel of the nitrometer. In use, as much of the substance to be tested is weighed out as the capacity of the nitrometer calls for (50, 100 or 140 cm.$^3$), and this, whether kieselguhr-dynamite, pyroxylins, etc., is placed in the funnel of the nitrometer. Then the rubber stopper and doubly bent thistle tube are inserted, and from 2 to 3 cm.$^3$ of concentrated $H_2SO_4$ are poured in the thistle. Naturally some of the acid remains in the bend of the tube and seals it, thus preventing the nitrogen oxides liberated during solution from escaping. When the solution is completed the three-way cock is opened and the fluid is drawn down into the measuring tube. Of course the acid in the bent thistle is drawn down with the fluid, and it serves the purpose also of rinsing the tube. The rubber cork and thistle tube are now removed and the second rinsing is effected directly in the funnel. The analysis is now carried on as usual, and when completed the liquid is forced back into the funnel. It has never yet occurred that the cock has been obstructed by the kieselguhr mixed in the acid, though such difficulty might have been apprehended. It is clear that the carbonic acid present would, under these conditions, cause no error.

To show how good the results by this method are, Lunge cites those obtained by B. Lee, chemist to the dynamite factory at Isleton, Uri, Switzerland. He examined collodion gun-cotton which had been dried first at 40° C. and finally over $H_2SO_4$. In Experiment I. the funnel of the nitrometer remained closed during the entire operation—that is, the $H_2SO_4$ for the rinsing, as well as that for the solution of the gun-cotton, was poured through the double-bent thistle tube. In Experiments II. and III., on the other hand, the dust on the sides of the funnel of the nitrometer was washed down with a little acid, and only after this were the rubber stopper and thistle inserted and the principal part of the acid run in. After the gun-cotton was dissolved and the solution drawn into the nitrometer the stopper and thistle tube were again removed and the rinsing carried on with uncovered funnel. The latter, therefore, only remained covered while the gun-cotton was dissolving, which was from three-quarters to one hour, the solution being accelerated by gentle shaking from time to time. During solution there was a considerable evolution of colorless gas-bubbles, due, apparently, to the decomposition of the carbonates contained

in the gun-cotton. As this decomposition takes place outside of the measuring tube, the $CO_2$ cannot cause an error in the measurement of the nitrogen oxides, as is the case when Hempel's or Lubarsch's nitrometers are used. The results are as follows:

| No. | Weight Gun-Cotton Used in Grams. | Vol. Gas Measured. | Barometer. | Thermometer. | Nitrogen per cent. |
|---|---|---|---|---|---|
| I. | 0.5252 | 113.1 cm.$^3$ | 725 mm. | 17° | 12.09 |
| II. | 0.5159 | 111.3 | 725 | 18 | 12.07 |
| III. | 0.5120 | 110.3 | 725 | 18 | 12.05 |

This proves that the method is an accurate one, even in the case where it is carried out, as in II. and III., in the simplest way.

The appearance of the above communication in the *Chemischen Industrie*, 273; 1886, led G. Alberts, chemist at the Nobel dynamite factory at Avigliana, near Turin, to describe his method of manipulation. Mr. Alberts has for the past two years been making analyses of gun-cotton with a Lunge nitrometer in the following way: The specimens are dried for about two hours at 40° C., then rubbed through a fine brass sieve; then an average sample of about 10 grams is taken and dried over $H_2SO_4$ to constant weight. A suitable quantity of this (about 0.48 gram) is weighed out in a 10 cm.$^3$ glass flask with ground stopper; the 140 cm.$^3$ nitrometer is prepared in the usual way, and then about 5 cm.$^3$ of concentrated $H_2SO_4$ are poured into the flask containing the gun-cotton, mixed with a platinum wire, transferred to the funnel of the nitrometer and drawn into the measuring tube as quickly as possible. The rinsing is several times effected by pouring portions of about 3 cm.$^3$ each of concentrated $H_2SO_4$ into the flask and transferring as before. Finally the platinum wire and funnel are washed in the same way. The total amount of acid used is from 15 to 20 cm.$^3$ The $CO_2$ present in the gun-cotton escapes during the treatment, and no development of gas has been observed in the funnel of the nitrometer. The following figures indicate the accuracy of the method:

| Ash Contained in Sample. | Nitrogen Observed. | Nitrogen in Ash Free Sample. |
|---|---|---|
| 0.86 per cent. | 13.40 per cent. | 13.52 per cent. |
| 2.40 | 13.20 | 13.53 |
| 2.16 | 13.24 | 13.53 |
| 1.80 | 13.30 | 13.54 |
| 2.60 | 13.20 | 13.55 |

The samples analyzed all came from the same nitrating process;

the difference in the amount of ash may be due to difference of treatment after nitration.

Alberts believes this method preferable to that with the bent thistle tube just proposed by Lunge, because not more than five minutes is required for getting the gun-cotton in the measuring tube, and the whole operation is completed in one hour; while with the thistle tube much time is spent in waiting for the gun-cotton to dissolve, and, besides, the oxides of nitrogen evolved in the funnel are lost. Lunge denies this latter assertion, as the liberated oxides are redissolved by the excess of $H_2SO_4$ present. The time lost in waiting for solution may be avoided by pulverizing the cotton as Albert does, and allowing it to enter the measuring tube before solution is complete. This will be better than treating in a separate flask, as that requires great skill and experience to avoid loss. ("The Analysis of Explosives," G. Lunge, *Ding. Poly. Jour.* **262**, 224–229; 1886.)

We have given in these Proceedings* the heat test as applied to dynamite and analogous nitroglycerine preparations. This has now been modified as follows:

Nitroglycerine preparations from which the nitroglycerine can be extracted in the manner described below must satisfy the following test, otherwise they will not be considered as manufactured with "thoroughly purified nitroglycerine" within the terms of the license.

This test, however, though at present looked upon as the most important, as far as testing the purity of nitroglycerine is concerned, is only one of several which any given sample of nitroglycerine preparation has to satisfy in order to establish its compliance with the definition of the license.

The test, although at present accepted as regulating and defining the meaning of the term "thoroughly purified," may, nevertheless, be modified or superseded if in the opinion of the Home Office such alteration may at any time be deemed necessary.

The apparatus required is: (1.) Test tubes from 5¼ to 5½ inches long, and of such diameter that they will hold from 20 to 22 cubic centimetres of water when filled to the height of 5 inches. (2.) The test tubes to be fitted with perforated corks, which should be conical, so as to fit all the tubes equally well. The perforations hold glass rods provided with a hook of glass or platinum to hold the test paper.

*5, 11; 1879.

(3.) The heating apparatus as prescribed with the original Government heat test.*

The test paper used is prepared as follows: 45 grains of white starch previously washed with cold water are added to 8½ ounces of distilled water; the mixture is stirred, heated to boiling and kept gently boiling for ten minutes; 15 grains of pure potassium iodide (*i. e.* which has been recrystallized from alcohol) are dissolved in 8½ ounces of distilled water. The two solutions are thoroughly mixed and allowed to get cold. Strips or sheets of white English filter paper previously washed with water and redried are dipped into the solution thus prepared and allowed to remain in it for not less than ten seconds; they are then allowed to drain and dry in a place free from laboratory fumes and dust. The upper and lower margins of the strips or sheets are cut off, and the paper is preserved in well-stoppered or corked bottles and in the dark. The dimensions of the pieces of test paper used are about $\frac{4}{10}$ inch by $\frac{8}{10}$ inch (10 mm. by 20 mm.).

The standard-tint paper is prepared by making a solution of caramel in water of such concentration that when diluted one hundred times (10 cm.$^3$ made up to one litre) the test of this diluted solution equals the tint produced by the Nessler test in 1 cm.$^3$ (?) of water containing 0.000075 gram of ammonia or 0.00023505 gram of chloride of ammonium. With this caramel solution lines are drawn on slips of white filter paper by means of a clean quill pen. When the marks thus produced are dry the paper is cut into pieces of the same size as the test paper previously described, in such a way that each piece has a brown line across it near the middle of its length, and only those strips are preserved in which the brown line has a breadth varying from ½ mm. to 1 mm. ($\frac{1}{50}$ of an inch to $\frac{1}{25}$ of an inch).

The apparatus required for treating the sample to be tested consists of a wide-mouthed bottle of about 6 ounces capacity to which is fitted an India-rubber stopper having two perforations. Through one of these passes a bent tube, and through the other a filtering tube. The latter should have sufficient capacity to hold about 500 grains of dynamite. Within the bottle is placed a small test tube to receive the nitroglycerine filtering through.

About 400 grains of dynamite, finely divided, are placed in the filtering tube (a small piece of cotton-wool having previously been into the contracted part of the tube) and made to fit it as

* *Loc. cit.*

evenly as possible by shaking and tapping; the upper surface is smoothed by gently pressing with a wooden rammer. Water is then poured on the top of the dynamite and allowed to sink into it by its own weight until a sufficient quantity of nitroglycerine has been displaced. The bent tube may then be connected with the filtering pump, or other means of reducing the pressure in the bottle, the displacement of the nitroglycerine being thus accelerated. The nitroglycerine collects in the test tube, and the operation is stopped before the water reaches the narrow part of the filtering tube. If any water should have passed through with the nitroglycerine, it should be removed with a piece of blotting-paper, and the nitroglycerine, if necessary, filtered through a dry paper filter.

In making the heat test, the thermometer is fixed so as to be inserted through the lid of the glass globe into the water (which is to be steadily maintained at a temperature of 160° F.) to a depth of 2¾ inches. Fifty grains of the nitroglycerine to be tested are weighed into a test tube in such a way as not to soil the sides of the tube. A test paper is fixed on the hook of the glass rod so that when inserted in the tube it shall be in a vertical position. A sufficient amount of a mixture of half distilled water and half glycerine is now applied to the upper edge of the test paper by means of a camel's-hair pencil, to moisten the upper half of the paper; the cork carrying the rod and paper is fixed in the test tube, and the position of the paper adjusted so that its lower edge is half-way down the tube; the latter is then inserted through one of the perforations of the cover to such a depth that the lower edge of the test paper is just above the surface of the cover. The test is complete when the faint brown line which after a time makes its appearance at the boundary line between the dry and moist part of the paper equals in tint the brown line of the standard tint paper.

The nitroglycerine under examination will be considered as "thoroughly purified," within the terms of the license, whenever the time necessary to produce the standard tint as above described is not less than fifteen minutes.

The heat test for blasting gelatine and gelatine dynamite is applied by intimately incorporating 50 grains of blasting gelatine with 100 grains of French chalk. The mixture is to be gradually introduced into a test tube of the dimensions prescribed in the dynamite heat test, with the aid of gently tapping upon the table, between the introduction of successive portions of the mixture into the tube, so that

when the tube contains all the mixture it shall be filled to the extent of 1¾ inches of its height. The test paper is then to be inserted and the heat is to be applied in the manner prescribed for the dynamite heat test, and the sample tested is to withstand exposure to 160° F. for a period of ten minutes before producing a discoloration of the test papers corresponding in tint to the standard color test which is employed for governing the results of the dynamite heat test.

The test for liquefaction of blasting gelatine and gelatine dynamite is made by cutting a cylinder from the cartridge to be tested, whose length is about equal to its diameter, the ends being cut flat. The cylinder is then to be placed on end on a flat surface, without any wrapper, and secured by a pin passing vertically through its centre. In this condition the cylinder is to be exposed for one hundred and forty-four consecutive hours (six days) to a temperature ranging from 85° to 90° F. (inclusive), and during such exposure the cylinder shall not diminish in length by more than one-fourth, and the upper cut surface shall retain its flatness and the sharpness of its edge. If the specimen to be tested be not made up in a cylindrical form, the above test is to be applied with the necessary modifications.

The test for liability to exudation of blasting gelatine and gelatine dynamite requires that there shall be no separation from the general mass of the sample to be tested of a substance of less consistency than the bulk of the remaining portion of the material under any conditions of storage, transport or use, or when the material is subjected three times in succession to alternate freezing and thawing, or when subjected to the liquefaction test hereinbefore described. (*Ann. Rept. H. M. Inspectors Explosives*, 1884; 63.)

*Dingler's Polytechnisches Journal*, **262**, 128–134, October, 1886, contains a valuable paper by Prof. Franz v. Rziha upon "The Mechanical Efficiency of Explosives." According to the researches of Bunsen and Schischkoff,* 1 kilo. of gunpowder develops a theoretical power of 67410 km., according to Stadler† 88157 km., and to Berthelot‡ 161500 km.; but these are all superseded by the results obtained by Roux and Sarrau.§ These latter exploded several varieties of gunpowder and other explosives in a calorimeter in the same way as

* Pogg. Annalen, **12**, 321; 1857, and Proc. Nav. Inst. **5**, 538; 1879.

† Zeit. d. oester. Ing. und Arch. **41**; 1886.

‡ Sur la Force de la Poudre, Paris, 1871.

§ Comptes rend. **77**, 138, 478; 1873.

Bunsen and Schischkoff had done, and they obtained the following results:

| One Kilo. of the Explosive. | | | | | Heat Units per 425 K. | Total Theoretical Work in Km. |
|---|---|---|---|---|---|---|
| Blasting powder, | $KNO_3$ 62%, | S 20%, | C 18%, | | 570.2 | 242335 |
| Musket " | " | 74 | 10.5 | 15.5 | 730.8 | 310590 |
| Cannon " | " | 75 | 12.5 | 12.5 | 752.9 | 319982 |
| Sporting " | " | 78 | 10 | 12 | 807.3 | 343102 |
| Gun-cotton | | | | | 1056.3 | 448927 |
| Dynamite, nitroglycerine 75%, kieselguhr 25%, | | | | | 1290.0 | 548250 |

From the value obtained for 75 per cent. dynamite we may deduce the theoretical work of one kilo. of nitroglycerine as follows (allowing six per cent. of the nitroglycerine to be consumed in heating the kieselguhr): $(548250 \times 100) \div (75-6) = 794565$ km. Again, from the values found for gun-cotton and nitroglycerine we may calculate the theoretical work of explosive gelatine composed of nitroglycerine 92 per cent. and gun-cotton eight per cent. thus: $(794565 \times 92) + (448927 \times 8) \div 100 = 766913$ km. According then to the researches of Roux and Sarrau, the four explosives principally used rank as follows:

| Explosive. | Theoretical Work in Km. | Relative Value. | |
|---|---|---|---|
| Blasting powder with 62% saltpetre, . . . | 242335 | 1.00 | |
| Dynamite with 75% nitroglycerine, . . . | 548250 | 2.26 | 1.00 |
| Explosive gelatine with 92% nitroglycerine, | 766913 | 3.16 | 1.40 |
| Nitroglycerine, . . . . . . . . . . . . | 794565 | 3.28 | 1.45 |

The last two columns give the relative efficiencies of these four explosives as deduced from theory. Approximately the same values have been obtained in practice in blasting. Thus experience has shown that to move one cubic metre of the same kind of rock, under precisely the same stratigraphic and other local conditions, by weight, two to three times as much blasting powder as dynamite will be required. Makuc,* director of the mines at Bleiberg, in a lengthy experience found the ratio for powder and dynamite to be as 1 : 1.84. From an extended experience in railway building, especially in the Buchberger cut, Von Pischof † found the following ratios for powder and dynamite:

* Oesterreichische Zeitschrift für Berg- und Hüttenwesen, 227; 1882; also Ding. Poly. Jour. **246**, 186; 1882.

† Trauzl, Dynamit und Schiesswolle, 147, Vienna, 1870.

| | |
|---|---|
| In medium hard syenite, . . . . . . . . . | 1 : 2.40 |
| In hard syenite or granite, . . . . . . . . | 1 : 2.57 |
| In felsite or quartzite, . . . . . . . . . | 1 : 3.30 |

The mean of these four results gives a ratio of 1 : 2.53, while Roux and Sarrau find a theoretical relation of 1 : 2.26.

Experiments have given the following relations between dynamite and gelatine:

| | |
|---|---|
| St. Gothard, railway,* . . . . . . . . . . | 1 : 1.46 |
| Zankeroda, mines,† . . . . . . . . . . . | 1 : 1.45 |
| Tarnowitz, excavation,‡ . . . . . . . . . | 1 : 1.41 |
| Mannsfelder, excavation,§ . . . . . . . . | 1 : 1.33 |
| Mean, . . . . . . . . . . . . . . | 1 : 1.41 |

while theory requires 1 : 1.4.

In the tests by Trauzl's method, where equal weights of the explosive are exploded in cavities in lead cylinders, and the efficiency measured by the increased volume of the cavities, the following results were obtained:

| Author. | Dynamite. | Gelatine. | Nitroglycerine. |
|---|---|---|---|
| V. Friese ‖ (Committee report), | 1.00 | 1.26 | |
| Münch,** . . . . . . . . | 1.00 | 1.57 | 1.86 |
| Trauzl,†† . . . . . . . . . | 1.00 | 1.43 | 1.43 |
| Dr. Klose,‡‡ . . . . . . . . | 1.00 | 1.50 | 1.80 |
| Mean, . . . . . . . . | 1.00 | 1.44 | 1.70 |

Here, again, we have a fairly close agreement with the theoretical values of Roux and Sarrau.

The theoretical efficiency of an explosive cannot be realized in useful work for several reasons—viz.: because of incomplete explosion; because of the compression and chemical changes induced in

* Tetmajer, Nobel'sche Präparate, 37, Zurich, 1882.

† M. Georgi, Jahrbuch für das Berg- und Hüttenwesen im König. Sachsen, 1882.

‡ Zeitschrift für das Berg-, Hütten- und Salinenwesen, 191; 1882.

§ *Ibid.* 246; 1881.

‖ Wochenschrift des oester. Ing. u. Architektenvereins, 144; 1883.

** *Ibid.* 205; 1882.

†† Trauzl, Ueber neue Sprengstoffe, 24, Berlin, 1883.

‡‡ Zeitschrift für das Berg-, Hütten- und Salinenwesen, 91; 1883.

the surrounding material; because of the energy expended in cracking * and heating † rock which is not displaced; because of the escape of considerable quantities of the gases through the blast hole and the fissures made by the explosion. In all probability the extent of this loss can never be determined by direct experiment, as the phenomenon of an explosion does not permit of close observation; nor can it be determined by comparison with the work done under other circumstances, as we are yet uncertain as to the so-called dynamic resistance of rock.

We are therefore met by a problem which for the present can only be solved by employing a technical analogy, and such a one is found in the firing from ordnance and small arms, where fortunately the work done by a powder charge has been determined with great precision. The use of the analogy is permitted because one can, according to the arrangement of the ball or tamping, shoot or blast with one and the same charge, and, therefore, with one and the same source of power, overcome resistance of two forms but of nearly equal magnitudes; and because, further, the process of burning the charge, whether in shooting or in blasting, is technically the same, for in each case the charge rests at the bottom of the cavity closed by means of the shot or tamping, and in each case the space occupied by the charge is increased through the chemical development of the gases so that the shot is moved forward in the bore or the tamping is compressed in the blast hole; and, finally, the practice of years has demonstrated that the greatest amount of useful work is realized either in shooting or blasting when certain relations of diameter, length and strength of walls on the one hand, and of size of charge on the other, have been attained.

Objections to the use of this analogy can only be based upon doubts as to whether the explosion is completed in the same time in both instances—that is, for the like release of power from the source—and whether the loss of gas is equal in both cases. These doubts are, however, so far as it is possible to observe, insufficient to prohibit the use of this analogy, since this is the only existing one, and the error connected with its use can in no case be great.

* Schell, Beobachtungen über Gesteinschwingungen in der Grube, in der Zeitschrift f. d. Berg-, Hütten- und Salinenwesen, 340; 1880, and 31; 1883; and M. Becker, Allgemeine Baukunde des Ingenieurs, 421; 1853.

† In rapid firing by artillery and infantry, from 10 to 15 per cent. of the theoretical work of the charge is spent in heating the piece.

| Kind of Musket or Gun | Weight of charge in kilos., $L$. | Weight of projectile in kilos., $Q$. | Observed initial velocity in metres, $v$ | Work done by charge in kilogram-metres. | Useful work per kilo. of powder, $\frac{Qv^2}{2gL}$ km. |
|---|---|---|---|---|---|
| Austrian infantry rifle, Wundl (old model) | .005 | .024 | 440.0 | 232 | 46464 |
| Austrian infantry rifle, Wundl (new model) | .005 | .024 | 453.0 | 251 | 50200 |
| Austrian 7 cm. field-gun | .350 | 2.900 | 299.0 | 13227 | 37791 |
| " 8 " | .950 | 4.300 | 442.0 | 39069 | 41125 |
| " 9 " | 1.500 | 6.400 | 448.0 | 65536 | 43690 |
| Krupp's armor-piercing gun (old mod.) | 205.000 | 776.700 | 502.4 | 9992000 | 48700 |
| " 40 cm. gun (1881 model) | 220.200 | 779.000 | 519.4 | 10716000 | 48664 |
| " 40 " (1884 model) | 279.200 | 741.000 | 615.2 | 14300000 | 51071 |
| French 34 cm. gun | 164.000 | 420.000 | 600.0 | 7710000 | 47012 |
| " 37 " | 246.500 | 535.000 | 600.0 | 9821000 | 39842 |
| Woolwich 23 cm gun | 149.800 | 172.500 | 728.6 | 5196000 | 34640 |
| " 34 " | 283.700 | 567.500 | 625.2 | 11310000 | 39866 |
| Elswick 23 cm. gun | 90.800 | 172.500 | 671.0 | 3960000 | 43612 |
| " 41 " | 408.600 | 817.000 | 616.1 | 15810000 | 38693 |
| " 43 " | 350.500 | 1000.000 | 558.8 | 15930000 | 45448 |
| Mean | | | | | 43788 |

If according to Roux and Sarrau we place the theoretical work of one kilo. of powder at 319982 km., then we may reckon that the available work, when fired in gun or musket, is $\mu = (43788 \times 100) \div 319982 = 13.71$ per cent.

In default of other data and methods of research, the useful effects of blasting charges of powder may also be placed at 13.71 per cent. The same value is also permissible for other explosives, since the foregoing discussion shows that the practical efficiency of explosives stands in the same relation as their theoretical efficiency. Consequently we have:

| Explosive. | Theoretical Work, Km. | $\mu = 13.71$ gives Useful Work, Km. | The Ratios of these Values. | |
|---|---|---|---|---|
| Blasting powder 62% saltpetre, | 242335 | 33224 | 1.0 | ... |
| Dynamite 75% nitroglycerine, | 548250 | 75165 | 2.2 | 1.0 |
| Explosive gelatine 92% nitroglycerine, | 766913 | 105144 | 3.2 | 1.4 |
| Nitroglycerine, | 794565 | 108935 | 3.3 | 1.5 |

The useful work of a blasting charge is employed two ways—viz.: partly in shattering the rock and partly in throwing or displacing the shattered masses. It is a familiar engineering problem to reduce the projectile force of a blast to a minimum (though for practical reasons it cannot be wholly dispensed with) by means of suitable-sized charges,

properly located in blast holes of estimated dimensions, and so avoid the cannonading of which the workmen are so fond. With the discovery of at least approximately correct values for the useful work of charges, we are now able to demonstrate the correctness of this principle.

The volume of the shattered rock is computed by the formula $V = k \times t^2$, in which $k$ is a coefficient determined by practice, and $t$ is the depth of the blast hole. For example, $t = 0.75$ m. and $k = 0.8$;* then $v = 0.34\ m^3$. In a certain stone of specific gravity $= 2.8$ the weight of explosive will be $Q = 0.34 \times 2.8 \times 1000 = 952$ k.

If for simplicity it is assumed that the charges were at less than 45° and that the mass is only thrown 10 m., then the work of projection will be $A = \frac{1}{2} Q W = \frac{1}{2}$ $(952 \times 10) = 4760$ km.

The blast acts in a hole 75 cm. deep and 30 mm. in diameter, which is charged to a depth of 20 cm. with dynamite of 1.6 sp. gr. and containing 75 per cent. of nitroglycerine. This charge weighs, therefore, $L = (7 \times 20 \times 1.6 \times 1000) \div 1000000 = 0.22$ k., and has a capacity for useful work of $a = 75165 \times 0.22 = 16536$ km. This action of projecting, then, has consumed $(84760 \times 100) \div 16536 = 29$ per cent. of the available useful work; whence it may be seen that, however general the calculation, this throwing of the *débris* is an evil, and represents a not-to-be-underestimated loss of available energy.

The *Engineering News* Publishing Co., New York, 1886, reprint from their journal the report of Capt. William H. Bixby, U. S. A., to the War Department on "New Ordnance Material in Europe," from which we extract the following account:

During the writer's visit to Magdeburg he had the opportunity of examining Gruson's new explosive of 1881,† which seems especially adapted to all military purposes wherever a safe but violent explosive is required. This explosive is composed of two ingredients which can be transported with perfect safety, are mixed only for use, and can be re-separated with ease at any subsequent moment. It is more powerful than nitroglycerine, safer than dynamite, produces no unpleasant effects upon those who handle it, and is cheap. In 1881–2 it was being tried by the German Government, but, as usual, all results were kept secret. The composition of this explosive is still kept partially secret. One ingredient is strong nitric acid, and the other

* Reiha, Lehrbuch der Tunnelbaukunst, **1**, 189, 192, 197.

† Proc. Nav. Inst. **11**, 771; 1885, and **12**, 616; 1886.

is a crystal; it is impossible to explode either alone, so that they are both perfectly safe as regards transportation. In order to make use of the explosive, the crystals are placed in the nitric acid, where they dissolve rapidly with a slight reduction of temperature; there is no chemical combination, but only a solution in this case; the mixture is then ready for use, but cannot be exploded by any ordinary method; for explosion it requires the use of a fulminating or detonating fuse twice as powerful as that used to explode dynamite. If, by any chance, after being thus prepared, the mixture is not required for immediate use, the addition of a little water dilutes the nitric acid to such an extent that the other ingredient is no longer held in solution; the crystals re-form, and can be separated by merely straining the mixture; the crystals are then dried (without the slightest danger), and are ready to be used again; the nitric acid is left in its diluted state and sold or used for other purposes. If the crystals are heated to a high degree of temperature, they burn, without explosion, somewhat like sealing-wax; neither ingredient alone, nor the mixture, can be frozen at any temperature above zero Fahrenheit. Neither the crystals nor the mixture produce any other unpleasant effects on the persons who handle them except the usual effect produced by nitric acid. The nitric acid is strong, but not fuming, yellow in color, and very pure.

The crystalline ingredient of this new explosive is Mr. Gruson's secret. It is a substance well known, to whose transportation there is no objection; it is, in fact, often transported to-day in commerce; it is not soluble in water, does not absorb water, and never becomes damp. Mr. Gruson discovered this explosive while experimenting to find some economical method for breaking up his old-iron chills. He thinks he has such facilities for its manufacture as will allow him to make it cheaper than other people.

In order to allow the use of this explosive within projectiles, Mr. Gruson manufactures two varieties of shells, each containing two compartments connected by a truncated conical opening, this opening being ordinarily filled by a solid conical plug. The liquid nitric acid is placed in the cavity on the side of the larger base of this conical plug, the cavity being lined with glass; the crystalline ingredient is placed in the other cavity on the side of the smaller base of the conical plug. If the shell is desired to explode when the shot strikes, the shell is made to contain at its forward end a percussion fuse opening into the first cavity containing the crystalline powder;

the conical opening above described connects this first cavity to the second cavity containing the nitric acid within its thin glass case, the conical opening being so placed that its plug has its larger base toward the rear of the projectile. When the gun is fired, inertia forces the conical plug out from its cavity into the compartment containing the nitric acid, and the two compartments of the explosives are mixed thoroughly by the rotation of the shell during its flight. The explosive is then ready to be exploded by the percussion fuse at the moment that the shot strikes any resisting object. In other shells, where it is desired that the shot should explode at a certain time after striking, the shot contains at its rear a chemical fuse connecting with the cavity containing the crystalline powder; in front of this latter is the compartment containing the nitric acid within its glass envelope; the conical opening connecting the two compartments is placed with the larger base of the conical plug turned toward the front, so that the plug cannot be disturbed from its position by any sudden forward movement of the projectile. When the shot strikes, the plug and the crystalline powder in its rear are driven by their inertia into the nitric acid; the whole is thus thoroughly mixed; the time chemical fuse, broken by the shock of striking, will cause the explosion of the whole mixture at the end of any given desired interval thereafter. In the latest model of these explosive shells, the glass case containing the nitric acid is cemented to the interior of another case of thin wrought iron. The latter can be introduced within the projectile when desired.

The percussion shells have been fired at long ranges, so as to land in ordinary hard ground. The explosion was so violent that the pieces of the shell flew rapidly in all directions, backward almost as far as forward, thus showing the intensity of the explosion. Such shells, exploding behind the interior crest of a parapet, would destroy material behind this parapet and would injure men who might consider themselves secure because they were sheltered from direct fire.

This explosive has been tested by blows from a pile-driver, in order to see how liable it is to explode under percussion. A weight of 112 kilograms (246 pounds) falling one metre broke the case of the fuse without producing explosion; falling three metres, it still failed to produce explosion.

Two examples may be quoted to show the strength of the explosion: First, a chilled-iron cylinder of 30 inches diameter was torn all to the powder which filled an 0.8-inch hole along its axis.

Second, one kilogram of the explosive was placed in a cast-iron shell of 75 pounds weight and exploded; the explosion tore the shell all to pieces in such a way that 240 of its fragments weighed in all only 37 pounds; the rest of the fragments were not to be found.

On the 29th November, 1881, the writer witnessed some experiments with this new explosive. The solid component looked like brown sugar, except that the crystals were needle-like, and nearly an eighth of an inch in length. When these crystals were placed in the flame of a Bunsen burner, they burnt slowly, in much the same way as sugar or sealing-wax, and with a good deal of smoke. Some of the crystals were put on an anvil and hammered without explosion. The crystals were then put into strong, but not fuming, nitric acid and were immediately dissolved. A few drops of the solution were put on the anvil and hammered without exploding. A piece of paper dipped in the solution was put in the flame of a Bunsen burner and burned in about the same way as the crystals had burned. A piece of paper put into the solution so as to serve as a wick was then ignited, and burned with increased flame, but without igniting the solution. Water was then poured into the solution, and the solid component recrystallized into white, flaky crystals. This recrystallization was accompanied by a slight *reduction* in temperature, hardly sufficient to be noticeable to the touch. Some of the explosive mixture was then placed in a thin metal tube in the ground outside the building and exploded by the use of a friction primer of triple the strength ordinarily used for exploding dynamite; the explosion produced a very effective result. The brown crystals were said to be poisonous if eaten, but not poisonous to produce any bad effects if simply tasted or handled. An actual test showed the writer that they were slightly astringent, with something of the taste of quinine.

Captain Piorkowski, Mr. Gruson's representative, was at Berlin on the 18th of November, 1881. On his return, he stated that the Prussian Government were going to continue experiments with the new Gruson explosive at Graudentz. The explosive does not yet work regularly enough, as it explodes sometimes one second only, and sometimes as much as ten seconds after impact. Mr. Gruson would like to have some other government besides Prussia experiment with this explosive, especially some government that would be willing to publish the results of its tests. He would not be willing, however, to make known the composition of the explosive unless in some way he could be first guaranteed a royalty or other compensation for the

4. That the gases produced by its explosion are probably much less injurious than those emanating from other explosives.

5. That this powder can be firmly compressed by rammers without danger, provided no sparks are evolved.

Still a third of these safe but violent explosives, available for many military operations, "ammonia-nitrate powder," has been brought to the writer's notice. In this explosive, ammonium nitrate forms the principal ingredient. This explosive was not tested in the writer's presence, but was said to be as powerful as dynamite, to fuse, but not to burn, in the presence of a flame, and to be exploded with difficulty under the blow of a hammer. This powder is said to be composed of:

| | |
|---|---|
| Ammonium nitrate, | 80 |
| Potassium chlorate, | 5 |
| Nitro-glucose, | 10 |
| Coal tar, | 5 |
| | 100 |

The explosion of this powder requires the use of a 10-grain fulminating cap.

Captain Bixby also states that the French Government have been experimenting with the use of celluloid for a waterproof covering of powder-cases. A rough wooden box was painted inside with one coating of celluloid. It was then filled with nitric acid and left for 24 hours. When then examined, the wood was found to be entirely untouched by the nitric acid. It is thought that the celluloid will prove so excellent a waterproofing for powder-cans and cases, that there will be no further trouble in keeping powder dry, even in the dampest localities.

He notes also the method for covering floors and other surfaces of magazines with "cork paint" as practised in England, and describes Cohausen's psychroscope for determining the relative hygrometric conditions of the external and internal atmospheres of the magazine.

The *Scientific American*, **56**, 101, Feb. 12, 1887, reprints from *Industries* an article entitled "Recent Progress in the Manufacture of Explosives," in which it says: "The various explosives now manufactured and known under the names of dynamite, sebastine, extra dynamite, petrolite, nitrolite, and possibly many others, consist of

nitroglycerine mixed with different proportions of solid materials, such as charcoal, gun-cotton, nitrate of potash, and different kinds of porous earth and clay. All these compounds have given rise to numerous accidents by reason of their spontaneously explosive nature. Many other nitro-compounds besides nitroglycerine have been suggested as explosive agents. Among these may be mentioned nitro-benzole, nitro-toluol, nitro-naphthaline, nitro-phenol, nitro-mannite, and the compounds obtained from starch, cellulose and sugar by the action of concentrated nitric acid.

"A German patent (No. 36,872) of Alfred Nobel, in Paris, covers the use of a mixture of metallic salts of acids rich in oxygen, *e. g.* nitrate, chlorate, or perchlorate, with one of the nitro-compounds of glycerine, sugar or cellulose. The barium, potassium and sodium salts are mentioned in the patent, and for blasting operations a mixture of from 75 to 80 per cent. of one of these salts, with 20 or 25 per cent. of nitroglycerine, is recommended. For firearms, 5 to 15 per cent. of nitroglycerine is added, or 10 to 30 per cent. of either nitroglycerine thickened with nitro-cellulose, or nitro-sugar, or nitro-cellulose alone, is substituted. These mixtures are said to be safe, and not liable to spontaneous combustion or explosion.

"A somewhat similar mixture has been patented by Jacob Engels, of Kalk, near Deutz (Nos. 36,705 and 10,232), in which the nitrate, sulphate, or chloride of ammonium is the salt added to the nitro-compounds. The composition of these explosives is somewhat complicated. They contain 5 to 10 per cent. pyroxyline, 70 to 60 nitroglycerine, 15.5 to 18 pyro-papier, 0.5 nitro-starch, 5 to 1 nitro-mannite, 0.5 nitro-benzole, 10 to 30 ammonium salts, 0.5 water-glass, and 8 to 10 of saltpetre. An explosive based on the same principle, and recommended for shells, is made from gun-cotton saturated with a solution of potassium chlorate (100 parts gun-cotton to 12 parts potassium chlorate), and then slowly dried at a temperature of from 62° C. to 75° C.

"The shells are filled with this compound by first making it into a paste with collodion (12 to 14 per cent.) and then allowing the mass to harden in the shell. This mixture is also said to be capable of withstanding a sudden shock without explosion. The double picrate of sodium and lead or barium obtained by mixing three equivalents of sodium picrate with one of lead or barium picrate is also the subject of another patent. The explosives in which these picrates are used have the composition: 15 to 30 per cent. barium sodium picrate,

lead sodium picrate, 2 to 10 potassium picrate, 20 to 5 nitro-aline, 40 to 20 potassium nitrate, 3 to 1½ sugar, 3 to 2 gum, o ½ of lampblack (English patent 14,140).

Carl Lamm, the director of the manufactory of explosives at olm, has come to the conclusion that one of the safest explo-onsists of a mixture of nitrate of ammonium with a di- or tri-nzine. The dinitrobenzines are easily obtained from benzine ct nitration with a mixture of nitric and sulphuric acids. All compounds are thus formed, the meta compound being in gest quantity. They are all soluble in alcohol, from which ı, on cooling, the meta compound crystallizes out first, while ho- and para-dinitrobenzoles remain in the solution. The ompound melts at 90°, and, when free from nitric acid, can be nchanged for any length of time. The trinitro compound is obtained from the meta compound by heating it with more cid and fuming sulphuric acid to 140° C. Numerous experi-have been conducted by M. Lamm with a view to ascertain-best proportions of these two substances to yield the maximum ve effect. He has named this mixture 'bellite,' and recom-its use as a substitute for the coarser kinds of gunpowder the larger firearms.

lite has the important quality of not being spontaneously ve; it can, therefore, be manipulated and transported without k. To cause it to explode, it is necessary to bring it into with a flame or with some substance that is strongly heated. ous experiments have been tried in order to determine whether ssible to explode it by a violent shock; but in the two years which these experiments have been carried on it has never ade to explode by a shock alone, or by friction. Both dinitro-and ammonium nitrate are stable compounds, if in their tion care be taken that there remains no excess of free nitric P. J. Cleve, the well-known professor of chemistry in the h University at Upsala, has confirmed these statements of coverer, and has certified that bellite may be stored, or trans-by railway, without any danger of spontaneous explosion.

lite appears to have a power which is greater than that of any explosives at present employed. In one experiment 15 grams ed by means of an ordinary fulminating cap, projected a shell ng 42.5 kilos. to a distance of 120 metres; and in experiments ting, bellite has been found to remove a greater quantity of

rock than that obtained by employing the same weight of explosives derived from nitroglycerine. The mean force of bellite is equal to thirty-five times that of ordinary cannon powder.

"The Swedish artillery have made a series of experiments with this new explosive that go to prove that when it is used for grenades, these grenades are not liable to spontaneous explosion by any sudden shock, and that when thrown and caused to explode by a convenient percussion fuse the results are superior to those obtained from grenades charged in the ordinary way with powder. Mines constructed with bellite are not set on fire or exploded even when struck by a bullet.

"The explosive force of bellite, compared with that of fulminating cotton, is as [illegible]. From these results it would appear that bellite marks a new departure in the history of the manufacture of explosive materials, and it would appear that from its valuable property of being incapable of explosion by shock or friction, we may not fear its application to the destruction of property in the same way that dynamite has unfortunately been used. M. Henry D'Estrey has lately brought this compound under the notice of the scientific public of France, so that we may hope that before long it may come into general use as a substitute for dynamite and the allied nitroglycerine compounds.

Recent experiments by the Minister of War at Berlin on new explosive materials have just been conducted at the island of Eiswerder near Spandau, and if this compound has been included in their investigations we may hope for further particulars of its properties in the report on the results."

[illegible] **91**, 880, 1880, states that M. Ruckstchell, [illegible] has invented a new explosive which he calls [illegible]. From experiments made at Camp Krasnoie Silo, near St. Petersburg, the new powder possesses a penetrative force ten times superior to that of ordinary cannon powder. Its explosion produces neither flame nor smoke, and is not attended with any detonation. It [illegible] that a motive force can be produced from this explosive [illegible] by a motor invented by M. Ruckstchell which is superior [illegible]

[illegible] announces the discovery of a substitute [illegible] primarily intended to replace the gunpowder used on

ge. The accidents which have happened to actors from the rge of firearms are so frequent that any means of preventing would be a boon to the profession. M. Edouard Phillippe, the or, showed the adaptability of his invention to the chassepot, *sil gras*, to old musketoons, revolvers, and for toy pistols made d. The explosive, fired at six paces, left no trace on a sheet e paper; whereas the plug from an ordinary stage musket left t distance an ugly black mark. The substance used by M. pe consists chiefly of phosphorus, and, the cartridge being lingly thin, the whole charge completely disappears. No trace to be found. The detonation, on the other hand, is as loud as roduced by gunpowder, the flame as vivid and the smoke ntly as dense, but it has the advantage of having no smell.

*leton's Annual Cyclopædia* for 1885, 342–347, contains a well-article on "Explosives," by Marcus Benjamin, Ph. B.

otes on Experiments with High Explosives," by M. M. Macomb, eutenant 4th Artillery, U. S. Artillery School, 1886, is the title ork of some 17 pages, with plates, which contains a detailed nt of upwards of 50 experiments in which dynamite, atlas pow-rcite, explosive gelatine, rackarock and tonite were employed stroying structures, disabling guns and gun-carriages, and ing fortifications. There is nothing new either in the experi- or the results (though it is always wise to place such results ord), but, if this represents the course of instruction at the ry School, it is an eminently practical and useful course.

*Professional Papers of the Engineer School of Application,* *A.*, **2,** 1–121; 1885 (?), contains a translation of the "Report Trials with Submarine Mines Executed Jointly by Sweden, Nor-nd Denmark, 1874–1876," made by C. W. E. Oxholm, C. E., Eng. Willet's Point. This translation is somewhat fuller than ublished in *Proc. Nav. Inst.* **7,** 121–154; 1881.

Bernard et Cie., of Paris, have published "Les Explosifs nes," by Paul F. Chalon, one volume, 420 pp., with 161 s. Spineux et Cie., of Brussels, announce the second edition of ériel de Guerre de nos Jours," by N. Adtz. The *Bibliotheca ico-Naturalis* notices "La Poudre à Canon," by M. Hélène, 1886.

# PROFESSIONAL NOTES.

## .ACTS FROM AN ARTICLE ON THE PROTECTION OF HEAVY GUNS FOR COAST DEFENSE.

By Captain G. S. Clarke, R. E.

*ed in the Proceedings of the Royal Artillery Institution, Woolwich, February*, 1887.

whole question of the choice of modes of protection will be found, on ration, to be closely bound up with the views which may be taken as to—
ıe probable accuracy of the fire of ships.
.e probable effect of shrapnel and common shell.
ıe probable effect of the fire of machine and quick-firing guns.
opting the barbette, open battery with embrasures, or the disappearing e, certain risks are obviously accepted. Is it worth while for the sake great advantages to accept these risks? To this very important ques- fferent answers will doubtless be forthcoming, since few will agree neasure of the risk, and the three points above mentioned admit—even much speculation. If a ship can, at frequent intervals, hit a barbette plant a shell fairly in the neck of an embrasure at moderate ranges; if eavy shell which strikes near the exterior crest of a parapet will plough through and burst in the battery, barbettes and embrasures stand con- . If the ship can drop the bullets of heavy shrapnel at a considerable f descent over the crest of a battery, overhead cover of some sort is uni- indispensable. If she can, with reasonable certainty, throw common ıich, striking a little short of the crest at a descending angle, blow in ıining wall on the gun and detachment, iron protection in some form eem to be inevitable. If, guided by a momentarily defined smoke-puff, asily able to land shells on an invisible target, the range of which can- exactly ascertained, the disappearing principle becomes questionable. if the ship cannot do these things now, is there any reasonable proba- ıat she will shortly be able to do so? Here is evidently a wide field for tion. The record of ship's practice cannot be kept like a rifle-shooting . Experimental firing against targets representing shore batteries is vely rare. We have practically only the experience of Alexandria on o build, and the easy victory obtained by the ships makes it all the less hat the lessons of the action will ever receive serious attention.
e are some essential differences between a naval attack on shore de- ıow and at the time of Algiers. Then the vessel enormously outmatched re batteries. A first-rate ship, with 66 guns to her broadside, was su- o almost any single battery. A fleet was immensely superior to a for- Where the shore works were open the ships could pour in an almost ous hail of shot and shell. There was room for plenty of bad shooting, there would be plenty of hitting, while the continuity of fire was de- ing in the extreme.* Even in much later days the United States fleet

* thus the ships did not invariably show a marked superiority over coast works unless the ere short. Such facts as the following are not without significance at the present day: In 5, Sir Sidney Smith," with the Pompée, an 80-gun ship; the Hydra, Captain Munday, and

poured 45,000 shot and shell into Fort Fisher in two successive bombardments, the rate of fire on the first occasion being given as 115 projectiles per minute. It is not surprising that the return fire was very ineffective and soon practically ceased. In the days of wooden ships the ranges were comparatively short.* At Acre the ships were quietly allowed to take up their assigned stations at from 600 to 700 yards from the defenses "before a shot was fired from the garrison." This was an advantage, inasmuch as the details of the work attacked could be well made out, the damage being inflicted was better seen, and the fire could be better directed. Moreover, mines and fast torpedo boats were non-existent, and if a ship could be laid alongside a shore battery—a course our naval commanders always strove to adopt†—she could crush the latter by sheer superiority of metal and rapidity of fire.

Conditions are now completely changed. The single ship will rarely outmatch the modern first-line battery. The fortress will far more nearly approach the fleet in weight of metal. Thus the Duperré carries only four 46-ton guns in her barbettes, and 14 broadside 5½-inch guns. The Inflexible has but four 80-ton guns and eight 20-pounders. It is doubtful if these two ships together would be a match for the six turrets of Fort Milutine at Kronstadt. The whole fleet engaged at Alexandria opposed 80 heavy guns to 36 on shore; but, on the one hand, the shore guns could not all be simultaneously employed, while on the other hand the actual gun power of the broadside ironclads must be halved. Compare the broadsides of the Inflexible and an old three-decker. With four 80-ton guns and four 20-pounders, the former ship can deliver 6880 pounds of iron at a single discharge. With 48 32-pounders, 17 8-inch guns and one 68-pounder, the latter delivered 2556 pounds. The 80-ton guns take five minutes to load, and the 20-pounders perhaps half a minute, the broadside of smooth-bores about one minute. Thus in five minutes the Inflexible fires 7600 pounds of iron, the wooden ship 12,780. The total *number* of projectiles in this time is, for the Inflexible 44, and for the wooden ship 330. Dealt with in this way, figures are not, perhaps, particularly valuable, and the above estimate is [illegible] favorable to the Inflexible, since the 20-pounder of to-day possesses [illegible] less relative value than the old 32-pounder, and would have little chance [illegible] a properly mounted heavy gun, while the Inflexible's 20-pounders [illegible] be served in face of moderately accurate shrapnel or machine-gun fire from the shore. Omitting them, the proportionate rate of fire between the [illegible] is 1 : 82.5.‡ In any case the importance of individual rounds is [illegible] increased, but it may fairly be doubted whether the possible [illegible] effect of a single projectile on well-designed works has been [illegible] augmented. It is conceivable that a single lucky 8-inch spherical [illegible] have dismounted a single shore gun and killed or wounded [illegible] detachment. A 16-inch rifle shell can do no more in a properly [illegible] battery, may even effect less, since a modern gun and its carriage [illegible] substantial traverse against splinters, while it is open to question

[illegible] a battery of two guns, situated on the extremity of [illegible] by a tower in which were 25 French soldiers." "The [illegible] was nearly ex- [illegible] destructive effect. The P[illegible], at which [illegible] her mizzen topmast carried away; a [illegible] and five men killed, and [illegible] men wounded. At length, force [illegible] after some [illegible] parley, the officer [illegible] of the two guns [illegible] failed on the second [illegible] so that in fact the [illegible] by a single piece of ordnance."—[illegible]

* [illegible] that the pilots would not accept the responsibility [illegible]

† [illegible] Exmouth's flag, was brought within 50 yards of [illegible]

‡ [illegible] in carriage and [illegible] the 20-pounders, arrives [illegible] the Inflexible's guns as [illegible], that a miss is enhanced by this number as a [illegible]

whether a line-of-battle ship, engaged at 500 or 600 yards, had not actually a better chance of obtaining such a hit than an Inflexible at 2000 yards. Comparing gun with gun, the accuracy of fire has immensely increased. Comparing ship with ship, the chances of hitting have probably diminished, notwithstanding that naval gunnery has greatly improved in the last thirty years. The ranges at Alexandria were somewhat long—less than half those adopted by the French at Sfax, however—but it is not certain that ships will gain a balance of advantage in future by closing with good shore batteries properly manned. They will, it is true, be able to bring their machine guns into action; but the effect of the latter will be neutralized in the case of B. L. guns by the protection which can be provided, and by better protected machine and quick-firing guns on shore. If the shore batteries consist of well-designed and dispersed barbettes, with good cover for the detachments, the effect of the fire of the ship will in some respects actually diminish as she reduces her range. Shrapnel will become useless. The disadvantage of the ship will be the more pronounced as the elevation of site of the battery increases. Her one considerable advantage is that being nearer she has a better chance of picking out and inflicting a direct hit on the shore guns themselves. But a shore gun offers a very small front target, and if the guns support one another well the ship will not always be able to get a broadside shot at one barbette gun without laying herself open to the close unreturned fire of another. The comparative targets of the single ship and single gun are enormously against the former, and if there is sufficient dispersion it is clear that it is this comparison which must be instituted and not that of the ship and battery. Practically, however, the ship will in many cases have little option in the matter of range on account of submarine mines and the action of fast torpedo boats; while, in most cases, it is possible for the designer of the shore battery to fix the minimum range at which a vessel of given type can engage it. If the tactics adopted by the French at Sfax—boats at "a few hundred yards," gun-vessels at about 2300 yards, ironclads at 7000 to 4300 yards—were tried against well-armed and well-fought shore batteries, the policy of the latter would be evident. First dispose of the boats with machine-gun fire and case; then sink the gun-vessels with common shell, treating them simultaneously with shrapnel; finally, commence deliberate fire with armor-piercing projectiles and common shell on the ironclads. The three operations can be successively carried on with considerable security. It will need a great deal of shooting from the gun-vessels before a shore gun is grazed, and the ironclads will do no harm at all to the defenses. At Sfax, after a remarkably deliberate fire of 2002 projectiles delivered under peace-practice conditions, the "defensive power" of the place is reported to have been "practically uninjured."

Some facts drawn from the Alexandria action throw a strong light on the question of the accuracy of fire to be expected from ships. Meks Fort, a prehistoric work, armed with five heavy R. M. L. guns, nine S. B. guns and five mortars, was engaged by the Monarch, Penelope, Invincible and Téméraire for about three and a half hours. During one hour the Inflexible contributed a portion of her fire. The ranges of the three first-named ships varied from about 1200 to 1000 yards, that of the Téméraire was 3500, and of the Inflexible 3800 yards. The Invincible and Téméraire were anchored throughout the affair. The guns of Fort Meks were practically all *en barbette*, the three heaviest of them firing over a 4-feet 8-inch parapet, the interior wall of which projected 1 foot 10 inches above it, with a thickness of 2 feet 6 inches. During the action not a single gun was dismounted or disabled, and two only were touched by heavy projectiles, which just grazed them, leaving indents 1¼ inches deep. One gun was knocked over by an 8-inch Palliser shell from the Penelope, fired at short range after the work was silenced, when, therefore, there was no return fire and no smoke enveloping the battery. The two grazes may of course have been similarly obtained. Altogether about 580 heavy and 340 light projectiles were fired at Fort Meks. Theoretically, of course, this work should

[illegible] may have [illegible]

[illegible] experiments were [illegible]

[illegible] against earth- [illegible] the most de- [illegible] in front of [illegible] been quite [illegible] dispersion. If the [illegible]

batteries are well traversed—the chances of such a hit are simply insignificant, even at moderate ranges. Where the guns have a good command such a hit can—as will be noticed hereafter—only be obtained at very long range. Moreover, the employment of iron glacis plates in front of barbette guns would give complete protection to the crest. Very effective results against men are obtained by a shell which, with a descending angle (the larger the better), just skims the crest and bursts on it or a few feet in rear. Are the risks of such a hit excessive? Large descending angles mean extreme ranges. If a time fuse is used, the accuracy required is measured in hundredths of a second. If a percussion fuse is used, it must be delicate and instantaneous, with a view of bursting on the crest, in which case it will be perfectly useless for purposes of weakening a parapet. If it does not graze the crest, it will, with all ordinary angles of descent, burst on the ground beyond, too far away to produce any serious loss. This, of course, presupposes that the emplacement is open to the rear, as it should be wherever possible. A common shell just clearing the crest of a circular pit* would catch the wall beyond and burst, probably killing every man of the gun detachment, and unquestionably so blocking the emplacement that it might take hours to clear the gun platform. In numerous existing cases guns are mounted close in front of walls admirably placed for increasing the dangerous target.

Again, to burst a common shell in the air in front of an earth battery with embrasures, or a barbette with a high parapet, is practically useless. This was fully recognized in Admiral Porter's orders before the attack on Fort Fisher: "All firing against earthworks when the shell bursts in the air is thrown away." . . . . "A shell now and then exploding over a gun *en barbette* may have a good effect, but there is nothing like lodging a shell before it explodes." It is doubtless an excellent thing to burst a shell directly over a gun, but it would be interesting to know how many a ship would have to fire before obtaining such a result. Some idea of the difficulty of obtaining much searching effect with common shell from ships' guns is conveyed by the fact that at 2400 yards the 8-inch howitzer, our best high-angle weapon, under perfectly favorable conditions, gave two effective hits in 20 rounds.

Tables of penetration into earth and sand have found their way into various text-books with no words of qualification. It is hardly too much to assert that they are totally misleading. Whatever may be the penetration attained in specially constructed butts, or arrived at by calculation open to objection, it is now sufficiently established that parapets of earth or sand with exterior slopes will not hold projectiles so as to enable them to penetrate properly. At Alexandria the penetrations, judged from a very large number of examples, were extremely slight. The shells turned up at once and either ricochetted high over the works or were stopped and lay on the superior slope, base to the front. A 16-inch shell from the Inflexible, fired at under 2000 yards range, was thus stopped after penetrating less than 20 feet of sand. As might be expected, this tendency to be immediately deflected is still more marked in the case of the new B. L. guns. At Eastbourne an 8-inch B. L. Palliser shell fired at 1193 yards gave a penetration of only 6 feet into a loam parapet with an exterior slope 1 in 2. At Lydd the effect of three 9.2-inch B. L. Palliser shells, fired at 1200 yards against a similar parapet, was almost *nil.*

It may probably be laid down, therefore, as an axiom that the fire of a ship is altogether unable to breach or seriously damage a properly constructed parapet; that exaggerated estimates of penetration must be modified, and that in works not liable to a land siege nothing is gained beyond a certain point by adding earth protection. The Eastbourne experiments further go to prove that shells bursting on a superior slope and causing craters which do not extend to the crest can effect no damage whatever in an emplacement.

The question of shrapnel is, perhaps, even more important, since shrapnel is to some minds a species of bugbear. The real effect of the 417 shrapnel

*At Inchkeith the back wall is actually heightened on the very centre line of the emplacement.

and segment fired at Alexandria is somewhat difficult to estimate. Only information from the Egyptian side could clear up the point. One gun and carriage received 49 shrapnel-bullet hits, all apparently inflicted by a single 11-inch shell from the Téméraire, the head and base of which were picked up in front. This gun fired through an embrasure the neck of which had been previously ruined by the fire of the Inflexible. Moreover, it is probable that the hit was delivered the day after the action. The remaining shrapnel hits on guns and carriages might be counted on the fingers, but it is of course possible that very oblique grazes might not have left a distinguishable mark. Some of the naval officers engaged at Alexandria were impressed by the good results of their shrapnel fire, but these results would be considerably enhanced by the defects of the Egyptian works. In estimating the Alexandria results, it is particularly necessary to separate those which the shortcomings of the works rendered inevitable. The fact that a ship could silence the fire of the saluting battery on the line wall at Gibraltar with shrapnel would not be a convincing argument of the efficiency of the latter against coast defenses generally. At Meks—a work almost *à fleur d'eau*—there was hardly a place where the head of an ordinarily tall man would be covered if he stood close to the parapet.

The Inchkeith experiments, carried out in August, 1884, throw a certain light on the performance of shrapnel at Alexandria. In all, 30 rounds were fired from the 10-inch R. M. L. guns at ranges varying from 850 to 3500 yards, the average being about 2330 yards. The conditions, so far as the ship was concerned, were ideal. The sea was calm; the ranges could be obtained with great nicety; the firing was by single rounds and excessively deliberate; undivided attention could be given to each round; there were no elements of disturbance; the Inchkeith gun presented an excellent target. On the first day, out of 15 rounds fired with battering charges, one ball found its way into the emplacement. On the next day full charges were used, and two good bursts were obtained in 15 rounds. Four dummies were hit; six balls struck the gun, six balls and three splinters the carriage and platform. In addition, one of the elevating wheels was broken, and the traversing gear placed at the rear of the platform was disabled by splinters. The gun could still have been worked.

The spread of shrapnel bullets from heavy R. M. L. guns has not been experimentally ascertained. For present purposes, therefore, it is assumed to follow the same law as that enunciated in the case of field guns by Lieutenant-Colonel Nicholson, R. A.* Taking the lateral velocity as constant and equal to 90 f. s., and the semi-angle of spread calculated as $\tan^{-1}\frac{90}{v}$, where $v$ is the velocity of the shell at the moment of burst, agrees in the case of the 64-pounder exactly with the result actually obtained at Dungeness. In the case of the 10-inch R. M. L., the spread similarly calculated varies from 3¾° at the muzzle to 5¼° at 4000 yards. With this gun, therefore, in estimating the searching effect of shrapnel, it will probably be sufficiently accurate to add five degrees to the angle of descent, unless the shell is burst so far short of the object that the increased curvature of the trajectories of the bullets becomes of practical importance. In the case of some new B. L. guns, the angle of opening of shrapnel has been experimentally determined, and found to be as follows:

| Gun. | Range, Yds. | Semi-angle of Opening. ° | ′ |
|---|---|---|---|
| [illegible]-inch B. L. Mark I | 2000 | 4 | 34 |
| | 3000 | 4 | 40 |
| [illegible]-inch B. L. Mark III | 1665 | 5 | 0 |
| [illegible]-inch | 1100 | 5 | 10 |
| | 2000 | 5 | 50 |
| | 3000 | 7 | 0 |

* [illegible] Fire."

† Calculated by Captain T. S. Jackson, R. N.

The possible searching effect will of course vary much with the height of the shore gun. Thus, with the service 10-inch M. L., using the 70-pound charge, a ship must be at 1750 yards distance to obtain a horizontal trajectory at the crest of a battery 300 feet high, while to obtain an angle of descent of six degrees she must move to 3350 yards. If the crest of the battery is 100 feet high, the corresponding ranges are 1050 and 2950 yards. A common shell arriving at an emplacement with a horizontal trajectory, can do little injury to the revetment wall. Striking only a few feet short of the crest, it will be deflected up, unless the burst is instantaneous, in which case (as proved at Eastbourne) the splinters all clear the emplacement. Practically, therefore, to be really dangerous, the shell must burst *exactly at* the crest, which means hitting a target a few inches high, as well as securing an instantaneous burst. Supposing a 10-inch R. M. L. shrapnel to be burst in the most favorable position possible, the bullets, in the case of a crest 100 feet above the ship's guns, will at 1000 yards have a drop of less than 11 degrees, and at 16 feet from an 8-foot parapet would be still five feet above the ground level. A just appreciation of the above facts will render apparent the difficulties under which the ship labors in delivering a searching fire, and perhaps serves to explain why the French ships do not carry shrapnel for heavy guns. These difficulties will be materially increased by the introduction of guns giving higher velocities. For example, the height of the new emplacements for B. L. guns on Stone-Cutters' Island, Hong-Kong, is about 210 feet. At this level, projectiles from the French 27 cm. gun with a muzzle velocity of 1664 f. s. will have a horizontal trajectory at 1750 yards, and a fall of 6°, or 1 in 9.7 only at 4000 yards. In the case of a higher-powered gun, such as our 9.2-inch, Mark III., with a muzzle velocity of 2065 f. s., the corresponding ranges would be about 2100 and 4800 yards. The searching power of the fire of modern ships is, therefore, strictly limited, and the difficulty of killing men behind a high parapet by shrapnel fire from high-velocity guns has, perhaps, been insufficiently appreciated; while the danger to the revetment in front of a barbette gun, or to the crest of a pit, cannot be regarded as serious.* As regards searching effect, ships are now in a worse position than they were 50 years ago, and when re-armed with new guns their power will in this respect be still further diminished.

It has been suggested that, in view of the difficulty above pointed out, a complete or partial return to short guns and low velocities is to be expected. It appears doubtful, however, whether our possible enemies, having arrived, after great efforts and vast expenditure, at remarkably straight-shooting long-range guns, will abandon them for relatively inaccurate weapons. This has certainly not been the practice in the past, and the resuscitation of smooth-bores—also at one time prophesied—is about an equally probable contingency. Again, though the value of curved fire of heavy shell from the coast battery against the ship is only now receiving general recognition, the use of howitzer fire from the ship supplies a ready argument against open batteries and disappearing guns. For several reasons, the result of the practice carried out from H. M. S. Hercules off Shoeburyness in August last was inconclusive. The fact nevertheless remains that, though the ship was anchored in smooth water, such an excellent high-angle gun as the 8-inch 70-cwt. howitzer was unable to plant a shell within 20 yards of a conspicuous target flag at only 1500 yards, and that two rounds fired with the same elevation and charge, on the same day, gave a difference in range of 370 yards. The admirable practice obtained at Lydd with this howitzer at 2400 yards is due to back-laying and careful observation. Howitzer vessels will have to engage at ranges not less than 4500 yards, or be quickly put out of action. It has yet to be shown how back-laying is to be carried out on board ship, how under ordinary conditions the clinometer

* General Sir L. Simmons stated in 1870, "What is the chance of a shot fired from an unstable platform, like the deck of a ship, striking a battery at 1600 or 1800 yards, so near the crest as to do any injury to it? I believe myself it would be absolutely throwing away ammunition to attempt it." (*R. E. Corps Papers, Vol. XVIII.*) High-velocity guns do not appear to have increased the chances of such a hit.

is to be employed unless the ship is aground, and how at long ranges observation from the tops is likely to succeed. The target offered by a disappearing gun will be an invisible horizontal circle some ten yards in diameter. The chances of hitting it may be imagined.

Some stress has been laid on the results which a modern ironclad might obtain from her auxiliary armament. Thus the Dupérré carries 14 5½-inch guns of new type and 12 Hotchkiss machine guns, in addition to her heavy armament. This auxiliary armament adds considerably to her total rate of fire, which, however, will still be inferior to that of a small frigate of old type. To use these guns, however, the Dupérré must fight broadside on, and as they have no armor protection, they would be in the same position, as far as protection is concerned, as the guns of a wooden frigate opposed to modern heavy-shell fire. If the shore guns were even moderately well handled, and especially if they were supplemented by a proportion of quick-firing guns, it might fairly be expected that this auxiliary armament would be very soon put out of action with a heavy loss in men; and it might be by far the best policy for such a ship to fight end on, using only her barbettes, and—except in the case of a battery on a high site—minimizing her target.

As regards the possibility of injuring the carriages of guns in shore batteries, the experiences of Alexandria were probably unexpected. Out of 35 R. M. L. guns under fire, there were, in addition to the dismounted guns, only two cases of injury of a damaging nature to carriages—a compressor arc broken and a front truck cut away by shell splinters. The case of a small, unfinished two-gun battery in Ras-el-Tin lines heavily shelled by the Inflexible and Téméraire is somewhat remarkable. The embrasures in front were almost destroyed and the guns bared, yet both carriages were perfectly serviceable and were subsequently mounted at Ramleh. The Alexandria affair seems to indicate clearly that, to disable a gun, a direct hit is necessary. It is worthy of note that two 9-inch Palliser shell, which actually burst in the turret of the Huascar, did not suffice to render either of the two carriages unserviceable.

As to the probable effect of machine-gun fire, the data, if not altogether complete, are extremely suggestive. Machine guns may be divided into two classes—1st, a continuously-fed gun, such as the multiple-barrel Gatling, Hotchkiss, Nordenfelt, and Gardner; 2d, a hand-loaded "quick-firing" gun. The former class is capable of delivering a very rapid fire of bullets or small shells; the latter fires shells up to about 6 pounds weight,* at the maximum rate of 10 or 12 per minute. At Alexandria the fleet carried about 70 1-inch 4-barrel Nordenfelts, and expended more than 16,000 bullets. The expenditure of Gatling ammunition was only 7000 rounds, and of Martini bullets 10,000. As to the results obtained, opinions have differed. It is submitted, however, that the number of hits on the guns and carriages of the defense may fairly be taken to afford some indication of those results. The hit of a Nordenfelt bullet on iron is generally unmistakable, but it is evidently possible that grazes at a very acute angle might have escaped observation. The total number of hits on guns and carriages was seven, and even this moderate number requires qualification. One hit was on the liberal target offered by the bracket of the Moncrieff carriage. This carriage stood upon the shore, the formality of building up protection round it having been omitted. The gun was of course not in action, and the natural fondness of the bluejacket for a good upstanding target can alone account for its being fired at.† The high exposed scarps of forts Ras-el-Tin, Adda and Pharos distinctly showed every Nordenfelt hit, but the total number of such hits was quite insignificant. It is stated that at the Ingogo affair, where the artillery suffered severely from rifle fire, the guns were actually whitened by bullet splashes. A fair inference seems to be that

* A [illegible] quick-firing gun, constructed at Elswick, has been tried with complete success, and [illegible] aimed rounds per minute. A 12-pounder gun is now under construction.

† [illegible] projectiles were also fired broadside on at this carriage, which received one [illegible].

the vast majority of the 16,000 bullets fell short, or, as was actually the case at Meks, flew well over the battery. Captain Fisher, R. N., states—"Most of our ships used their Nordenfelt machine guns, but nothing is known as to the effect produced. The bullets were found far and near, so it is to be feared the fire was not very accurate. It is difficult, indeed almost impossible, to see where the comparatively small Nordenfelt bullet hits." The conditions at Alexandria were not unfavorable to machine guns. The ranges of the inshore squadron were moderate, and the tops of the ships were above the level of the shore guns. Captain Lewis, R. E., in his lectures on "Permanent Fortification,"* remarks—"It might be quite possible for a boat armed with a machine gun to keep a heavy gun silent—that is, if the boat could manage to begin." It is not easy, however, to see why a boat firing at the water level should succeed, while the machine guns in the tops of the Penelope and Invincible failed for three and a half hours; and this opinion can only be regarded as the outcome of pure theory uncorrected by actual experience. The explanation of the apparent failure at Alexandria is, doubtless, that the ranges were, on the whole, too great for accurate practice under service conditions, and that, even at the less ranges, the smoke of the guns of the attack and defense, together with the sand thrown up and smoke caused by the shells bursting, utterly obscured the effect of the Nordenfelt guns, so that the men who served them had no idea where their bullets were going. Diagram III. shows the influence of high sites in modifying the searching power of the 1-inch Nordenfelt gun. A fall of 2° (1 in 28) at a crest 100 feet high can only be obtained at 1040 yards. In the case of the Hong-Kong emplacements above referred to, this angle of descent is unattainable at a less range than 1260 yards.

The experiments carried out at Inchkeith, where H. M. S. Sultan, under the conditions stated on p. 175, concentrated her fire on a single remarkably conspicuous shore gun, form an interesting comparison with the Alexandria results. The total number of machine-gun rounds fired was 15,210, by which fifteen dummies were hit. In the first four series 1541 rounds were fired, with the result of hitting one dummy. In the other series four Gardners and two Gatlings on deck fired 2815 rounds, obtaining three hits on dummies. In another thirteen machine guns fired 3874 rounds, hitting two dummies. This was target practice and the dummies remained fixed in the most exposed positions which the loading numbers could occupy.† Making the most moderate correction for the complete difference of conditions under which an action would have to be fought, it does not appear that even a barbette gun has much to fear from machine-gun fire, and the Alexandria results seem to be explained. The most that a ship could hope to do, by directing her whole machine-gun fire on a single shore gun, would be to keep it silent for a short period at an extravagant expenditure of ammunition. A few machine guns on shore would effectually prevent even this moderate achievement.

As to the performance of the 6-pounder quick-firing gun also, the Inchkeith experiment affords some teaching. In forty-eight rounds, at ranges from 1500 to 1900 yards, one dummy was hit. On the other hand, in five subsequent rounds the target gun—turned broadside on—was hit three times; but since, in this case, thirteen machine guns were simultaneously in action, the effect on the dummies cannot be stated. This excellent result shows the kind of target practice of which the 6-pounder is capable; but it may fairly be questioned whether its introduction has not conferred superior advantages on the defense. Against the unarmored portions of a ship it will prove extremely effective, and to keep the crew behind their armor and the officers shut up in conning-towers will be a considerable gain. In any case the quick-firing gun itself will

* R. E. Occasional Papers, Vol. VII., 1882.

† Nos. 2 and 3 stood always *on* the loading stage, about half their bodies being fully exposed. No. 5, who was supposed to serve the muzzle derrick—a duty he could have performed with a boat-hook from the loading-way in perfect security—stood actually on the platform girder, and was exposed down to his knees.

probably not be carried behind armor, and the unarmored portions of a ship may be expected to suffer very severely in the first action in which modern coast-guns are properly handled.

The introduction of heavy breech-loaders for land service affects the question of protection in the following ways: The length and comparative weakness of the chase are somewhat unfavorable. Even with the otherwise complete protection promised by a casemate, cupola, or turret, the great protrusion of the gun will render it liable to a hit which might easily disable it. At Eastbourne the shell of a 6-pounder Hotchkiss quick-firing gun, striking the chase of a 10.4-inch B. L. gun, penetrated into the bore. At Shoeburyness a steel shell from the same quick-firing gun, striking the chase of a 9.2-inch B. L. gun at 150 yards, raised a bulge 0.4 inch high in the interior. The precise effect of such an injury cannot be stated. A portion of the chase of the damaged gun would obviously be blown off by the next round fired, and more serious consequences are evidently possible. The effect of a projectile from the quick-firing gun striking the face of the muzzle of a heavy gun has not been ascertained. Again a single shell from a 6-inch B. L. cut off two feet four inches of the chase of the 10.4-inch B. L. gun, and even the 5-inch B. L. is capable of inflicting serious injury at comparatively long range. To chase injuries, guns *en barbette* are not more liable than those in turrets; while long guns in casemates may evidently be seriously damaged by medium B. L. guns outside their arc of possible reply. In one sense, therefore, the introduction of long guns has reduced the value of front armor, since there is a partial anomaly involved in providing a mass of iron which, after all, leaves the weakest portion of the gun it affects to shield exposed to injury from light projectiles. It is to be remembered, further, that the considerable amount of smoke issuing when the breech is opened constitutes an argument of some importance against mounting the new guns in casemates or roofed turrets. A breech-loader, however long, can be loaded *en barbette* while offering a minimum target to front fire of all kinds, and if the operation is performed at elevation the actual loading numbers are admirably protected by the breech of the gun itself. Unless, therefore, the fire of more than one ship can be concentrated upon individual guns, which, with dispersion, careful sighting and a moderate angle of training, will not be easy to effect, the loading numbers of new B. L. guns *en barbette* will be well protected in spite of their greater distance from the parapet; while the great disadvantage attached to side loading in the case of M. L. guns—the presentation during considerable periods of a broadside target—will be obviated. On the other hand, the breech mechanism brings a new source of danger. A mere burring up of the breech-screw by a machine-gun bullet, or the cutting away of the locking lever by a shell splinter, might suffice to silence the gun for a long time. These risks can, however, be easily met by a steel hood enveloping the breech, or by special steel protection to individual points of weakness.

Von Scheliha, in his treatise on "Coast Defense," says: "Guns mounted *en barbette* may always be disabled by an ironclad." The remark might with advantage have been made more general. All guns, however mounted, *may* be disabled by an ironclad, and the question is merely one of comparative risk. The Grüson plates of the great Spezzia cupola, four feet two inches thick, and each weighing very nearly 91 tons, will provide no protection whatever for the long, weak chases of the two 16-inch guns, which could be disabled by the projectile of a 5-inch B. L. gun carried on board ship. Under these circumstances, it is not surprising that the barbette principle still finds favor, and that it is not proposed to give front-armor protection to any of the guns mounted in the new coaling-station defenses. A barbette gun cannot well be disabled except by a direct hit, and the vulnerable target presented to front fire is little larger than the breech section. It has been asserted that the new B. L. guns cannot be held in a barbette mounting, and that turrets, cupolas, or casemates fitted with cumbrous "yokes," are, therefore, necessary. The 9.2-inch B. L.

gun has been held at Lydd by an extemporized anchorage in shingle, and has also been successfully mounted on board ship. The 10-inch B. L. has for some time been mounted *en barbette* at Cadiz and successfully fired. The 43-ton 12-inch has also been tried on a barbette mounting. This objection may, therefore, perhaps be abandoned.

The drawbacks to this mode of mounting are two—exposed flanks, and the absence of overhead cover to the detachment. The maximum angle at which the gun can subtend at the ship—in other words, the area of the target—can be limited to any extent desired; while the practical carrying out of systematic cross-firing from ships will not be quite so easy as it appears on paper. The ship may be expected to show a natural tendency to concentrate her fire on the guns which are hitting her; and if the Inflexible, at Alexandria, had been hulled every other minute from Oom Kabébé, she would not, in all probability, have divided her fire so impartially between this work and Fort Ras-el-Tin.

Of all methods of mounting yet proposed, the disappearing principle offers the greatest advantages, and, provided that the mechanical difficulties can be overcome, this method will receive a wide adoption. The gun, laid under cover by a position-finder, will be vulnerable only for a few seconds before each round. Its exact position can only be identified during the brief period of visibility. There appears to be no satisfactory mode of attacking it.

The experiments carried out at Portland Bill in November, 1885, give some idea of the difficulty a ship will experience in dealing with a gun of this class. The dummy—a wood and canvas model of a 10-inch B. L. gun—appeared and disappeared on the natural surface of the bluff, working up and down through an opening in a wooden shield at the ground level. The period of visibility laid down by the conditions of the trial was half a minute in every three minutes, and a small charge of powder was fired electrically at the moment of disappearance to represent the discharge of the gun. H. M. S. Hercules, at ranges varying from 750 to 950 yards, fired 6910 rounds in ten minutes from 1-inch and rifle-calibre machine guns, and 29 rounds from the 6-pr. Hotchkiss quick-firing gun. The whip used for hauling down the dummy unfortunately broke at the end of the 7th minute. For the three following minutes, therefore, the dummy was exposed and, as the ship continued her fire after the bearing laid down had been passed, it presented a broadside target. Notwithstanding that the dummy was exposed more than twice as long as it was intended to be, and about four times as long as a real gun need have been, it received only 16 direct and 9 splinter hits. The horizontal wooden shield showed four scratches, and one Nordenfelt bullet dropped into the gun pit. It would, of course, be perfectly useless to employ machine-gun fire at a disappearing gun; but the above result supplies an interesting comparison with that obtained by a simi-
... at Inchkeith. To halve the number of hits obtained at Portland,
... the unfortunate accident to the whip, is more than fair,
...tion of these hits were undoubtedly obtained when the
...disappearing and presented a broadside. Accepting this
...ison of hits on the guns at Inchkeith and Portland is
... the average ranges in the two cases were as 1000 to 825
...n addition, 15 rounds of 10-inch common shell and 13
...rapnel were fired at the Portland dummy at ranges from
...ithout any result whatever. In the common-shell series,
...ried from 300 yards short to 300 yards over, and the hori-
... yards left to 150 yards right, showing clearly the difficul-
... such a target.

...t, although by no means satisfactory from either the point
... defense, serves nevertheless to substantiate the advan-
...appearing system. These advantages can obviously
..., however, by applying the system as at Newhaven,
... Corradino Lines, Malta.

... which it has been sought to arrive at may be stated

1. The all-round protection conferred by the turret will be sure to recommend it, but expense, combined with other considerations, will limit its adoption to low, cramped, advanced or island sites. The great range of modern guns will somewhat check the tendency to push forward the shore gun to the water's edge, where a high site suitable for a barbette is available within a few hundred yards to the rear. In any case, the provision of a turret can be justified only where a disappearing mounting is proved to be impracticable. Limitations of range due to considerations of the size of the port of a turret will not be tolerated. The heaviest guns will therefore be port-pivoting, and will be worked by hydraulic power, proved to be perfectly successful on board ship. At distant foreign stations, where there are no facilities for repairs, the turret can, under no circumstances, be adopted. In very hot climates it may prove inadmissible. Where there are moderately high sites of sufficient area it is altogether unnecessary. The relative inaccuracy of the fire of ships renders it probable that a turret would not be frequently hit in action, and the fact that, as proved at Buchau, a single segment of a Grüson turret broke up under four closely adjacent hits from a 12-inch gun, does not condemn chilled-iron armor. Such a favorable result would never be attained by ships in action. The question between wrought iron, steel, and cast-iron armor is, therefore, mainly one of economy. A sand or earth parapet up to the level of the glacis plate will be provided, where practicable, as at Kronstadt. In other cases, a gentle slope of hard concrete will be substituted.

2. The cupola, understanding by the term a conical turret containing a single gun worked by hand, is subject to some of the above limitations. The Eastbourne experiments showed that a cupola, the strongest plate (7-inch compound) of which was shattered by three 8-inch B. L. shrapnel striking blind, approached the limit of hand-working. The adoption of a floating pivot would doubtless facilitate rotation to a great extent; but it seems probable that a cupola to justify its existence must carry a weight of armor necessitating the employment of power, and thus become subject to the same limitations as the turret, of which it is a mere modification. An inadequately armored cupola appears to be quite as dangerous as a barbette mounting, while it is far more expensive.

3. The continuous iron front or the Grüson battery may still be employed under certain circumstances—for example, on a cramped, low site where great volume of fire is required over a limited arc, or where an all-round fire is needed of limited intensity on a given arc, but such that the flank and rear guns shall be available after those in front have been silenced. In such a case, "position-finding" would be a necessity, since the smoke produced by the large charges now employed renders the direct laying of casemate guns entirely dependent on chance conditions of wind and weather. Armor may also conceivably be desirable to protect machine or quick-firing guns in connection with turrets. This form of protection will usually labor under the disadvantage of offering a large target and involving heavy expense, while it will sometimes entail crowding of guns where dispersion is possible. As in the case of the turret, range cannot be sacrificed to size of port, and port pivoting, probably necessitating hydraulic power for the larger nature of guns, must be adopted.* The thickness of metal in an armored front should be well able to withstand the heaviest projectiles that the attack is likely to bring to bear upon it, and the possibili[illegible] of subsequent strengthening should not be lost sight of. Since cast-iron [illegible] cannot well be subsequently strengthened, a Grüson battery should [illegible] resistance decidedly greater than that now required.

4. The disappearing principle will undoubtedly attain great de[illegible] other mode of protection confers equal invisibility. A di[illegible]

* Port-pivoting has already been partially attained by the "small[illegible] [illegible]-inch and 12.5-inch M. L. guns, but [illegible] the great [illegible] extremely limited. Guns thus mounted would, therefore, [illegible] position-finder.

well-placed pit provided with a horizontal splinter-proof shield is far better protected than in an impenetrable turret. Moreover, a gun so mounted possesses the great advantage that future advances in the offensive power of ironclads are little likely to diminish the value of its protection. For the new breechloaders the counterweight carriage is unsuitable, and hydro-pneumatic mountings have not yet by any means reached their full development. It has been shown that these mountings can be satisfactorily applied to the 8-inch B.-L. gun,* and experiments shortly to be tried will test their application to the 9.2-inch and 10-inch B. L. Experts hold that the principle can be extended without any great difficulty to the 68-ton B. L. gun. Were several adjacent guns to be thus mounted, it may prove desirable to provide a small steam engine, able, by pumping, to ensure the maintenance of the pressure necessary to raise the guns. The engine would be merely a reserve of power intended to save manual labor, and to meet the case of leaky glands or defective cup leathers. For the old muzzle-loaders there is no reason that a counterweight system, such as that of Colonel Moncrieff or Major King, should not be employed for guns up to the 10-inch R. M. L. The system need be applied only in cases where low sites, with deep water within short range, are unavoidable. The Moncrieff mounting is necessarily costly, but the gun is far better protected than if mounted in a casemate with a heavily armored front, while in the opinion of the special committee appointed to consider the question of counterweight carriages, one disappearing gun may be estimated as equal to two in casemates. A simpler system may possibly be devised, and rate of fire might perhaps be sacrificed in consideration of the great protective advantages. The value of the disappearing principle greatly depends on the way in which it is applied to the actual site. With adequate care the position of a gun so mounted may in most cases be rendered absolutely indistinguishable except during the few seconds of exposure before firing. If, however, this fact is not fully recognized, the system loses one of its special advantages.

5. The principle of the Collingwood mounting appears to be eminently applicable to coast-defense guns of the heaviest class. The measure of protection provided is practically equal to that of a turret. It is true that this protection is far inferior to that conferred by the disappearing principle, but the practicable difficulties in the case of the heavier guns are possibly less. The target offered to the ship is so small that the comparatively slight risk of a direct hit—almost the sole danger to which a gun thus mounted is liable—may perhaps be accepted without hesitation. The loading numbers have complete security. With the heavier guns hydraulic power must undoubtedly be employed, and there appears to be no better mode of applying it. Whether the hydro-pneumatic principle can be applied to this mounting, so as to realize a storage of recoil, and enable several guns to be worked by a small engine, remains to be seen. The addition of an armored glacis will be desirable in the case of low sites, and it is possible that chilled iron may be suitable for the purpose.

6. The barbette, with a central pivot, is likely to be the most general form of mounting. The heaviest of the new guns at present tried with this mounting is a 43-ton B. L gun, firing a charge of 400 pounds. Whether heavier guns, up to the extreme limit of hand-working, can be thus treated, remains to be seen. With the larger natures a front pivot may be necessary, and hydraulic power must be employed. The main danger of the barbette mounting is on the flanks, and protection should rarely be sacrificed to a wide angle of fire, where it is possible for an unengaged ship to take up a flank position. An angle not exceeding 120 degrees, with bonnettes, will be the most generally suitable; but to lay down an arbitrary limit is evidently undesirable, and each case must be dealt with on its merits. Circular pits are objectionable, but much less disad-

* The fact that this mounting—on its first trial—stood 46 rounds, including 5 rounds with 210-pound proof cylinders, with charges varying from 105 to 112 pounds Prism[1] (black), without a breakdown, is most encouraging.

vantageous on high sites. The emplacement should have the minimum possible of exposed masonry above the line of descent of heavy projectiles fired at a range of 3000 yards. It may prove desirable to protect with iron the crest over which the gun fires, especially where considerable depression is required. The Eastbourne experiments show that a skin of iron plate supporting good concrete would be a suitable form of crest, but it is possible that the place of concrete may advantageously be taken by sand alone. The range must not be diminished by limiting the possible elevation. Since the carriage designed at Elswick for the 43-ton gun admits of 20°, this limitation would not appear to be necessary. The protection of exposed gear on the side of the carriage and of the breech screw (when withdrawn) from the chance hit of a shell splinter, as well as the whole question of steel hoods to cover the loading numbers, merits careful attention. Under some circumstances the front pivot and embrasure will be advantageous. It is now certain that the results of experiments with siege guns need not be held to condemn the embrasure for coast batteries. Should the difficulty of under-cover loading for the existing M. L. guns prove incapable of satisfactory solution,* it may be worth while to accept the limited angle of training and adopt the embrasure for these guns, mounting a larger number of guns to cover the same field of fire, in order to gain the considerable protection against shrapnel and machine guns which the embrasure affords to the loading numbers. Bonnettes with vertical stone cheeks 8 feet high, as at Fort Leonardo, Malta, and elsewhere, will scarcely be repeated, and earth or sand will be universally employed. Guns *en barbette*, except in cases where a sky background cannot be avoided, may be rendered almost invisible at moderate ranges. Even the 100-ton guns at Malta are extremely difficult to make out at 2000 yards; those at Gibraltar could easily be rendered at least equally inconspicuous.

7. In sighting guns, dispersion will be aimed at as much as possible, and the placing of the most powerful guns of a battery in closely adjacent emplacements will always be avoided. High sites will be preferred for open batteries. Against the more heavily armored modern ships, the attack on the deck may possibly prove by far the most effective course. Barbette ships seem specially ill-qualified to resist such an attack. The very accurate fire of the new guns will be favorable to it. It is true that the flatter trajectories will produce a relatively greater tendency to rebound from the deck plating, but, on the other hand, there are plenty of objects on the deck of a ship capable of turning down a projectile, and once turned down it would be rash to attempt to predict its further course. The importance of high sites and dispersion was clearly pointed out by Sir Harry Jones forty years ago:—"It becomes the duty of the engineer charged with the defenses of a maritime fortress so to arrange his batteries that the defenses may be from several points distant from each other . . . . on commanding situations and not *à fleur d'eau*, which has heretofore generally been the case. As auxiliaries, batteries so placed on many occasions will be found very useful, but for the principal defense height must be attained."† Todleben drew the same moral from the remarkable effect produced by the fire of the telegraph battery at Sebastopol, and naval men have never hesitated to own their dread of plunging fire. There is no ship afloat which could not be put out of action by such guns as the 6-inch and 8-inch B. L. mounted on high sites, and it may be desirable in some cases to sacrifice even a thousand yards of range to gain the double advantage of plunging fire, and relative immunity from risk.

8. Invisibility will be striven for by all possible means. It is the cheapest form of protection. Guns will be suitably colored. Clean-cut lines and even slopes will altogether disappear, while vegetation will be judiciously encour-

* The chain-rammer experiments carried out with a 9-inch R. M. L. gun at Eastbourne in July, 18?5, cannot be regarded as altogether satisfactory. The average time per round was 3 minutes 19 seconds, and the difficulties of ramming increased after a few rounds.

† Editor's note—"Peninsular Sieges."

aged. The background and foreground of gun emplacements will be made the subjects of careful study. At Alexandria the great difficulty of our ships was to find a definite object to aim at. In a well-designed earth battery there should rarely be anything clearly defined. The very few natural advantages of the Alexandria sites can be improved upon in most cases, provided that the necessary amount of care and thought is forthcoming.

9. Parapets 35 feet thick, with flat exterior slopes, will be ample for all purposes of protection, and are likely to be equally serviceable years hence. Sand will be employed in front of gun emplacements wherever possible. A mere layer two or three feet thick on the top of an earth parapet has been found to be advantageous.

10. Since it is now certain that ships will have to anchor, or come back to a given point to fire, when seriously engaging earth batteries, the employment of curved fire against them will in time obtain wide adoption. The fact that, with an 11-inch howitzer at 7300 yards, five shots out of ten were placed on a target representing the deck of the Inflexible,* is sufficiently significant. Later experiments in Russia and Italy fully bear out this excellent result, while the depression position-finder opens out new possibilities. Already the Italians are mounting howitzers in large numbers for coast defense—at Venice the numbers of howitzers and guns are 45 and 22 respectively, three forts being armed with howitzers only. The U. S. Board on Fortifications propose 144 12-inch rifled mortars for the defenses of New York alone. The heaviest ironclads are exposed to deck attack by means of curved fire, and the moral effect of this fire, delivered from small groups of heavy howitzers, will suffice to prevent them from anchoring or even manœuvring at slow speed within range. The service 9-inch R. M. L. gun, re-tubed and polygrooved, has given excellent results used as a howitzer. The larger natures of short R. M. L. guns will before long be similarly utilized, and will be much improved in range and accuracy. The proper employment of large howitzers is to group them in fours behind natural folds of ground, or banks rendered indistinguishable from their surroundings, employing salvo-fire directed by a position-finder. The re-tubed guns will, in many cases, be adapted also for direct fire ; but when thus used their value as howitzers is impaired by their necessarily increased visibility. It is, therefore, desirable to regard the two modes of employment of these guns as completely distinct, and while mounting them in some cases so as to retain the power of direct fire at moderate ranges, to provide concealed howitzer batteries in addition.

11. The defense will employ machine and quick-firing guns in dispersed emplacements, well separated from those of the heavy guns. This auxiliary armament can be rendered practically invisible at moderate ranges, and should find no difficulty in keeping down the fire of corresponding guns on board ship, as well as thoroughly searching the unarmored portions.

12. The advantages in respect to range-finding, and the direction and concentration of fire which the shore battery possesses over the ship, deserve to be utilized to the utmost possible extent. The position-finding system devised by Major Watkin, R. A., has attained perfection. Its practical value has been amply attested by experiment, and its general application cannot be much longer postponed.†

In conclusion, it is maintained that, having regard to future possibilities, the defense must proceed rather in the direction of scientifically increasing the many tactical and other difficulties of the attack than in merely piling on front armor. It may be doubted whether thickness of iron or steel will ever exercise a determining influence on an action between ships and coast defenses. The Amiral Baudins and Lepantos can be defeated without ever penetrating their thickest plates. The want of practical experiments in naval gunnery has

* Journal R. U. S. Institution, 27th January, 1882.

† The Russians have had a system of position-finding in practical operation at Kronstadt and Sebastopol for some years.

naturally resulted in anticipations as to the effect of the fire of ships which can never be fulfilled. Without waiting for Alexandria, it could probably have been established that vessels in motion are quite unable to silence guns in dispersed emplacements even at low levels, and this fact alone would have been worth ascertaining. There are many more points on which light might have been thrown by such experiments as those at Inchkeith and Portland. The back of the Rock of Gibraltar, the island of Filfilla, off Malta, offer convenient sites; while a suitable island could probably be found on the west coast of Scotland. The expense would surely be justified, since, after all, the chances of being hit materially affect the settlement of most questions of coast defense. If such questions are to be ruled mainly by mere considerations of armor penetration, and the battle between coast defenses and ships is regarded—as has sometimes been the case—in the light of a mere contest between the gun and the plate, how are we to forecast the future?

Lecturing in 1873,* Lieut. (now Major) English, R. E., one of the most able exponents of the iron method, stated:—"The development of curved fire, which would appear to be the most likely method of attack, would surely not be such a difficult task as the development of armor-piercing projectiles. It is almost certain that no material improvements will be made in the shape and material of the latter; and it appears probable that the limits of weight and velocity are already nearly reached, on account of the difficulty of finding any material to withstand the strains produced in the inner tubes of heavy guns by the enormous charges even now found requisite. We may, therefore, venture to hope that comparatively little, if any, further expenditure will be necessary to maintain the present invulnerability of our iron coast defenses."

Curved fire from ships cannot be said as yet to have received any "development," unless, indeed, the proposed construction of a cruiser carrying four Zalinski air-guns for the United States Navy can be regarded in this light. Meanwhile, the improvement in armor-piercing projectiles has been extraordinary, as was brought home to most minds by the recent performances of the Firminy shell. The 12-inch 35-ton gun of 1873 has a muzzle velocity of 1390 f. s.: the 9.2-inch B. L. wire gun of to-day has 2500 f. s. The maximum internal strains are being reduced.† The projectile of the 35-ton gun weighs 714 pounds; that of the 100-ton guns, now several years afloat—the Duilio was launched in 1876—weighs about 2000 pounds. The 10-inch R. M. L. of 1873 burns 70 pounds of powder; the 10-inch B. L. of 1886 at least 250 pounds. The inadequacy of most of our "iron coast defenses" is a matter of common notoriety, and large sums would be needed to restore an "invulnerability" which was even rendered doubtful by the introduction of the 38-ton gun in 1874.

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## REPORT OF TORPEDO ATTACK AND DEFENSES OF U. S. S. TENNESSEE.

NORTH ATLANTIC STATION,
U. S. FLAGSHIP TENNESSEE (FIRST RATE).
NEWPORT, R. I., *September* 21, 1886.

Rear-Admiral S. B. LUCE, U. S. N.,
*Commanding U. S. Naval Force on North Atlantic Station.*

*Sir*:—In compliance with your order of the 17th inst., directing me to furnish a description of the torpedo attack and of the defenses of this ship on the night of the 16th inst., etc., I have the honor to submit the following regarding the attack, and append a copy of the rules by which the torpedo boats

* R. U. S. Institution, 31st March, 1873.

† Thus, in the 100-ton R. M. L. gun, 469 pounds P[2] gave a pressure of 20.8 tons; while 551 pounds Fossano powder produced only 17.37.

were to be governed. These rules were made by Commander Goodrich, U. S. N., umpire, and two officers of the Torpedo Station who were to be of the staff of judges—with myself as commander of the defense.

In anticipation of the attack, the ship was defended as follows and as more fully shown by the accompanying drawing:

The defenses forward consisted of the fore and main topsail yards lashed together at the outer end and spurred out by the flying jib-boom from the cut-water, the after ends being spread out by the fore and main topgallant masts from each bow. The forward torpedo spars were lowered and guyed well forward and the intervening spaces filled out with the fore and main trysail gaffs, one on each side. There was a guy from the jib-boom to the end of the flying jib-boom to secure the latter in position and as an additional security to the heel-lashing. The flying jib-boom was guyed from the forward end to the ship's side. The defense astern was composed of the cross-jack yard on the starboard side and several smaller spars and pieces of timber lashed together into one compact mass on the port side. The after ends were lashed together and spurred out by the mizzen topgallant mast directly astern. The forward ends were spread out and lashed to the fore and main topgallant yards as outriggers from each quarter. The after torpedo spars and lower booms were rigged out and drooped into the water. The mizzen topsail yard was used amidships on one side and the spanker gaff on the other side as spurs. Additional spurs were made by lashing capstan bars to the ends of the boat strongbacks, making them thirty-five (35) feet long, and placed along the ship's side at intervals of about forty (40) feet, the heels being lashed at the water's edge to the steel ridge-rope, which was passed around the ship and set up forward, and which is shown in red ink in the accompanying sketch.

An eight (8)-inch hawser was middled, the bight secured to the outer ends of the after booms and the ends carried forward on each side and set up taut to the outboard ends of the fore and main topsail yards and strongly lashed to the outer ends of the spurs at the uniform distance of thirty-five (35) feet from the side. A seven (7)-inch hawser, similarly secured, was lashed on six (6) feet inside of the first, capstan bars were then lashed to the two hawsers, athwartships, at regular intervals between the spurs, the ends protruding outboard two or three feet, the idea being that the thrust by the torpedo boats should be taken up by the two hawsers, instead of by the one, and the protruding ends of the capstan bars to disable the launches. On the port quarter a netting was secured as a propeller-catcher and rope ends were allowed to trail from the spur ends for the same purpose. The outer hawser, by means of tricing lines and topping lifts on the spurs, was triced up from the water about six inches, in order to prevent its being submerged by the boats upon striking. Eight improvised torpedoes were distributed along the defenses, to be fired at will from the firing-board on the after bridge. In addition, the Hotchkiss revolving cannon, Gatling gun and the two howitzers were fully manned, and assisted in the defense, together with the marines as sharpshooters. Four streams of water (two from the steam and two from the hand pumps) were also made use of to represent the firing of machine guns.

As soon as darkness had fully set in, four picket boats were sent out to a reasonable distance, one four points on each bow and one four points on each quarter, each with orders to patrol over an arc of four points each way, and on the discovery of an enemy to fire a Very's signal.

In further preparation, the machine guns and 3-inch howitzer were manned, pumps worked, a judge at each gun (officers of the Naval War College and Torpedo Station), and bright lookouts kept from prominent parts of the ship.

Soon after, the alarm was given from the picket on the port quarter, followed by that on the starboard quarter and both bows, showing that the enemy intended striking on both bows and quarters. Machine guns, howitzers and hose were ready. All the boats of the attacking force were put out, in accordance with the rules, before any damage was done; but, notwithstanding this, several per-

sisted in attacking, one in particular on the port beam making repeated attempts to carry away the defenses, but without success.

The umpire having decided the attack finished, the gun to signify the fact was fired, attacking boats came alongside and reported to the judges, who after consultation decided that the attack was wholly unsuccessful.

A thorough examination of the defense on the morning of the 17th showed that the defenses were intact, without the slightest injury.

I would mention that the boats were not supplied with torpedoes, that only primers were used in our defensive ones, and that our main battery was not fired for fear of accidents.

The Hotchkiss, having no blank cartridges, and the 3-inch not working well with the same, were also not fired, but kept bearing on the attacking boats as they were discovered. Sharpshooters fore and aft on both sides and the Gatling used blank cartridges as the attacking boats came within their vision.

Very respectfully,
Your obedient servant,
ROBT. BOYD, *Captain, Commanding*.

RULES GOVERNING ATTACK BY TORPEDO BOATS AND DEFENSE OF U. S. S. TENNESSEE AGAINST SUCH ATTACK.

Any boat, in the opinion of the judges, that is under fire for fifteen seconds shall be ruled out.

Any boat getting inside of obstructions within twenty feet of hull will be considered as having made a hit.

Any boat claiming a hit will blow a whistle—prolonged blast—and then remain in position, quiet, until decision is announced.

Boats will be assigned a number. When in the opinion of a judge a boat is ruled out, a Very's signal will be discharged in the direction of the boat, and as soon after as possible that boat will answer by blasts of the whistle corresponding to number of boat.

When any boat is ruled out, the officer in charge of boat will immediately withdraw his boat to a reasonable distance and await recall.

At the termination of the exercise a gun will be fired, when all boats will assemble alongside.

A judge at each machine gun.

Decision of judge final.

Differences of opinion by judges to be decided by umpire.

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## THE REEL LIFE BUOY.

INVENTED BY NAVAL CADET ARMISTEAD RUST, U. S. N.

This buoy is designed to be used on board seagoing vessels of all kinds for the purpose of rescuing in the shortest possible time any person who may happen to fall overboard, and to recover man and buoy without the necessity of lowering a boat. It may also be used to rescue the crew of a ship in distress at sea in heavy weather. The reel is wound with about half a mile of steel wire rope about one-quarter of an inch in diameter. The axle is fitted with a crank at each end, and is mounted to turn with the least possible friction. The reel is fitted with a strap friction-brake, and is mounted on a revolving platform, and may be securely held in any position by a set screw. The buoy is hung below a platform built out over the ship's stern, and is in form of a small life-boat, the bow, stern and sides being air tanks of sheet metal, and the bottom an iron grating. To give stability there is a heavy narrow iron keel which fits up close under the bottom of the buoy when it is suspended at the stern ; but when the buoy is detached, this keel drops, and

is held in position some distance below the bottom of the buoy by three iron rods sliding in vertical pipes which are secured in the air tanks and centre of the buoy. There is just space enough in the centre of the buoy to afford standing-room for one man. When suspended at the stern the buoy is held steady in a sea-way by vertical rods which extend down from the platform and pass through pipes in the buoy. On top of the buoy are two metal standards, each supporting a metal box, with cover, for holding the composition known as "port fire." When the buoy is detached the covers are removed automatically, and the lights ignited by friction primers. In one air tank there is a small locker for holding a Very's signal pistol, food, water, etc. On each side of the buoy is a movable fin, which is rigged out at first and remains so until it is desired to reel up, when the fins are rigged in by the man in the buoy. They are to prevent the buoy from being towed until the man overboard gets inside. Electrical connection may be made between the buoy and ship by an insulated copper wire passing through the centre of the wire rope, so that signals can be exchanged in foggy weather, when the lights would not show. The buoy is provided with eye-bolts for hoisting, and suitable life lines. There is also a bottle of oil so arranged as to break when the buoy strikes the water, and a can to furnish a further supply, to smooth the sea in the neighborhood.

The following advantages are claimed:

1. Means of recovering man and buoy without lowering a boat.
2. It is so constructed as to remain practically stationary in the water if so desired.
3. It may be controlled from the ship and hauled up to the man overboard.
4. Means are provided for signalling from the buoy.
5. The man is protected from sharks, and his strength not exhausted by hanging on, and he is provided with food in case the line parts and the buoy cannot be picked up for several days in heavy weather.
6. The buoy is dropped and the lights lighted by moving a single lever, it has great buoyancy and stability, all parts are simple and not liable to get out of order, and it is light and easy to hoist.

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# REPORT ON EXPERIMENTS MADE TO DETERMINE THE BEST METHOD OF DRYING GUN-COTTON PRIMERS FOR SERVICE USE.

TORPEDO STATION, NEWPORT, R. I., *April* 22, 1885.

*Sir*:—In obedience to your order, we beg leave to submit the accompanying chart of curves, representing the different methods of drying gun-cotton as called for by our order of November 25, 1884, with remarks upon each curve and the conclusion arrived at by the Board,

We also append the results of analysis made by Mr. J. F. White, chemist, at the request of the Board, to determine what effect, if any, $CaCl_2$ will have upon gun-cotton, wet or dry, exposed to its influences.

Very respectfully,

(Signed) J. S. NEWELL, *Lieut.-Comdr.*, *U. S. N.*
( " ) E. W. BRIDGE, *Lieutenant*, " " "
( " ) J. F. WHITE, *Chemist.*

Commander W. T. SAMPSON, *U. S. N.*,
*Inspector of Ordnance, in Charge of Station.*

CHART OF DRYING CURVES.

Net percentages of water are shown on the left; time (in days) at the bottom and top.

Curve No. 1 shows the result of exposing the discs to the air of a large room warmed by a stove.

Five discs, their average weight being 423.96 grams, were placed on a fine wire screen in the lecture-room of the chemical laboratory, the room being heated by a large stove, for twenty-three days, and their weight noted daily. At the end of the twenty-third day, the discs having ceased to lose weight, two of them were exposed to calcium chloride ($CaCl_2$) under two conditions—*i. e.* in a vacuum and not in vacuum—for twelve days more; and three discs were exposed in a steam dryer for sixteen days (the temperature of the dryer for seven hours each day (9 A. M. to 4 P. M.) averaging between 90 degrees and 100 degrees F.). At the end of these times the discs had all ceased to lose weight and showed an average total loss of $30\frac{6}{10}$ per cent. net.

From this we assume that the average discs originally held 31 per cent. net of water, and that the loss due to exposure to air was equal to 29½ per cent. net. And from the assumption that the discs originally held 31 per cent. net of water, we find the net average weight to have been 323.6 grams.

At noon each day the temperature, wet and dry bulbs, was recorded as follows:

| | Room. | | Temperature Outside. |
|---|---|---|---|
| January 15 | Dry 58 degrees. | Wet 50 degrees | 40 degrees. |
| " 16 | " 57 " | " 50 " | 35 " |
| " 17 | " 64 " | " 55 " | 48 " |
| " 18 | " 54 " | " 45 " | 30 " |
| " 19 | " 56 " | " 47 " | 31 " |
| " 20 | " 51 " | " 43 " | 16 " |
| " 21 | " 58 " | " 48 " | 36 " |
| " 22 | " 38 " | " 34 " | 16 " |
| " 23 | " 42 " | " 34 " | 24 " |
| " 24 | " 54 " | " 45 " | 34 " |
| " 25 | " 50 " | " 45 " | 40 " |
| " 26 | " 52 " | " 44 " | 36 " |
| " 27 | " 43 " | " 36 " | 23 " |
| " 28 | " 42 " | " 34 " | 20 " |
| " 29 | " 38 " | " 32 " | 13 " |
| " 30 | " 55 " | " 47 " | 34 " |
| " 31 | " 62 " | " 51 " | 45 " |
| February 1 | " 56 " | " 48 " | 45 " |
| " 2 | " 52 " | " 41 " | 18 " |
| " 3 | " 51 " | " 42 " | 28 " |
| " 4 | " 55 " | " 45 " | 32 " |
| " 5 | " 64 " | " 53 " | 44 " |
| " 6 | " 45 " | " 38 " | 24 " |
| " 7 | " 44 " | " 36 " | 28 " |

Curve No. 2 shows the result of exposing the discs in an outhouse with no artificial heat.

Ten (10) discs were taken and placed in an outhouse January 2, 1885, where they were sheltered from storm or bad weather, and only exposed to the air of the house. No current or draught of air or artificial heat. The ventilation of the house was obtained only when the doors were opened, and of these there were two, one inside the other. The house was practically sealed up. From time to time the discs were removed from the house to the laboratory, where they were weighed and then returned.

Curve No. 3 shows the result of piercing the discs with a number of holes similar to the one required for all primers to be used in the contact torpedoes, and exposing them to the air of a large room warmed by a stove.

Five (5) discs, each having six holes bored through them, were placed upon a fine wire screen so that the discs had air space all around. The discs were subjected to the same treatment as those represented by Curve No. 1, the average gross weight being 420.4 grams, and when dry showing an average loss of $34\frac{4}{5}$ per cent. net. We assume that originally they held 35 per cent.

net of water, and that their loss due to exposure in the room was equal to $33\frac{6}{10}$ per cent. net. From the assumption that the discs originally held 35 per cent. of water, we find their net weight to have been 311.4 grams. The temperatures are recorded with Curve No. 1.

(Note.—This curve should have its origin at 35 per cent., and after the fifth day will conform very nearly with Curve No. 1.)

Curve No. 4 shows the result of exposing the discs in the hot air of the steam dryers.

Four discs, their average gross weight being 412.4 grams, were placed in a steam dryer, service pattern, the steam being supplied from a cylindrical boiler (about one foot by one foot) placed on a stove in an adjoining room. Steam was supplied from 9 A. M. to 4.30 P. M. daily, the temperature of the dryer being noted every hour. The dryer was run daily until the discs ceased to lose weight. The discs were weighed daily at noon, and the temperature of the open air (out-doors) was noted. On the twelfth day it was found that the average loss during the preceding 24 hours was one-fifth of one per cent., and the discs were removed. The total average loss was found to be 33.6 per cent. net. From this we assumed that the average discs originally held 34 per cent. net of water, which gave a net weight for the discs of 308.6 grams.

The average temperature for the dryer, while in operation each day, as well as the temperature of the open air at noon, is shown in the following table:

| | | Average Temperature of Dryer for 7½ hours, 9 A. M. to 4.30 P. M. | Temperature Outside at Noon. |
|---|---|---|---|
| March | 30 | 102 degrees F | 56 degrees. |
| " | 31 | 103 " | 54 " |
| April | 1 | 107 " | 56 " |
| " | 2 | 107 " | 46 " |
| " | 3 | 107 " | 58 " |
| " | 4 | 102½ " | 40 " |
| " | 5 | 98 " | 42 " |
| " | 6 | 107½ " | 50 " |
| " | 7 | 100 " | 61 " |
| " | 8 | 106 " | 49 " |
| " | 9 | 107 " | 44 " |
| " | 10 | 107½ " | 58 " |
| " | 11 | 108 " | 56 " |

To obtain a comparison between the use of the boiler mentioned and the one issued with a dryer, one of each was put in operation and continued for several days, the result giving an average temperature for the service boiler of 96.8 degrees, and for the one used in experiment 97.8 degrees.

Curve No. 5 shows the result of exposing the discs to $CaCl_2$ (calcium chloride), the tank being frequently opened and the air not exhausted.

Four (4) discs, their average gross weight being 391.7 grams, were treated as those in Curve No. 9, except that the air was not exhausted. The tank was opened on the fourth, eighth, twelfth, sixteenth, twentieth, twenty-third, twenty-fifth, twenty-sixth, twenty-seventh, twenty-eighth and twenty-ninth days, the discs weighed and the $CaCl_2$ dried. It was found that after the twenty-fifth day the discs did not lose weight, and on that day the total loss amounted to 30½ per cent. net. From this we have assumed that the average discs originally held 31 per cent. net of water, which would give the discs a net weight of 299 grams.

Curve No. 6 shows the result of exposing the discs to $CaCl_2$ (calcium chloride), the tank being seldom opened and the air not exhausted.

Four (4) discs, their average gross weight being 398.9 grams, were treated in a manner similar to those of Curve No. 9, except that the air was not exhausted and the tank was first opened on the sixteenth day and on the twentieth, twenty-third, twenty-fifth, twenty-sixth, twenty-seventh, twenty-eighth

and twenty-ninth days, the discs being weighed and $CaCl_2$ dried. It was found that the discs practically ceased to lose weight after the twenty-fifth day, and on that day the loss amounted in all to 32¾ per cent. net. From this we assume that the average discs originally held 33 per cent. net of water, which would give a net weight for the discs of 300 grams.

Curve No. 7 shows the result of exposing the discs to the sun in the open air.

Five (5) discs were exposed to the sun, and, when the sun was not shining, kept in a closed box in the chemical laboratory, which building was warmed by a stove. These discs, when exposed to the sun, rested upon a shellaced board and were placed under the shelter of a bank. The experiment began December 30th, 1884, and was continued 45 days, ending February 13th, 1885. During this time the discs were weighed before and after exposure. At the end of the 45 days the discs ceased to lose weight.

Average gross weight, 432 grams.

| | | | |
|---|---|---|---|
| Exposed to sun | 165 hours, | suffered loss | 68.3 grams. |
| Not " " " | 919 " | " " | 25.7 " |
| Total, | 1084 " | " " | 94 |
| | 45⅓ days, | " " | 28.5 per cent. net. |
| | | Leaving in discs | 2.5 " " |
| | | | 31 " " |

A record of weather and temperature during this time is appended:

RECORD OF TEMPERATURE AND WEATHER, DISCS EXPOSED TO THE SUN.

| Day. | Temperature Noon. | Weather. | Wind. |
|---|---|---|---|
| Dec. 30. | 60 degrees. | Clear, pleasant and mild. | Moderate southward and westward. |
| Jan. 2. | 23 " | Clear and cold. | Fresh northward. |
| " 3. | 23 " | Clear, cold and pleasant. | Light airs northward. |
| " 5. | 41 " | " " " " | " " westward. |
| " 8. | 44 " | Fresh and pleasant. | " " northw'd and westward. |
| " 9. | 52 " | Cloudy " " | Fresh southward. |
| " 10. | 36 " | Clear and cold. | Strong westward. |
| " 13. | 38 " | Clear and pleasant. | Fresh northward. |
| " 14. | 39 " | " " " | Light northward. |
| " 19. | 31 " | " " cold. | Northwest. |
| " 20. | 29 " | " " " | Northwest. |
| " 21. | 36 " | " " pleasant. | Strong southward and westward. |
| " 22. | 16 " | " " cold. | Strong northward. |
| " [illegible] | 24 " | " " " | |
| " [illegible] | 30 " | " " " | Fresh northwest. |
| " [illegible] | 23 " | " " " | Light northwest. |
| " [illegible] | 13 " | " " " | |
| [illegible] | 34 " | " " " | |
| [illegible] | 45 " | " " pleasant. | |
| [illegible] | 18 " | " " cold. | Strong northwest. |
| [illegible] | [illegible] " | " " " | Light airs northwest. |
| [illegible] | [illegible] " | " " pleasant. | Northward and westw'd. |
| [illegible] | [illegible] " | " " cold. | Northwest. |
| [illegible] | [illegible] " | " " " | Light northward and westward. |
| [illegible] | 31 " | " " cloudy. | Northward and eastward. |
| [illegible] | 48 " | Clear. | Northeast. |

RECORD OF TEMPERATURE AND WEATHER, DISCS NOT EXPOSED TO THE SUN.

| Day. | Temperature Noon. | Weather. | Wind. |
|---|---|---|---|
| Dec. 31. | 48 degrees. | Mild, foggy. | Southward. |
| Jan. 1. | 45 " | Cold and rainy. | |
| " 4. | 34 " | Cloudy, snow and rain. | |
| " 6. | 50 " | Rain. | Eastward. |
| " 7. | 45 " | Cloudy, mild. | Southwest. |
| " 11. | 40 " | Cloudy and cold. | |
| " 12. | 50 " | Rain. | Strong southwest. |
| " 15. | 40 " | Rain. | Southward and eastward. |
| " 16. | 35 " | Rain. | |
| " 17. | 48 " | Cloudy. | Moderate gale southwest. |
| " 18. | 30 " | Clear and cold. | Northward. |
| " 24. | 34 " | Stormy, snow and rain. | |
| " 25. | 40 " | Cloudy, damp rain. | |
| " 28. | 20 " | Cold, snow. | |
| Feb. 1. | 35 " | Rain and snow. | Variable. |
| " 4. | 32 " | Cold and foggy. | |
| " 5. | 44 " | Cloudy, clear. | Light airs westward. |
| " 6. | 24 " | Snow, cloudy, sleet. | Fresh northward. |
| " 8. | 28 " | Cloudy, snow, sleet. | |
| " 9. | 40 " | Cloudy and damp. | Eastward. |
| " 10. | 42 " | Foggy. | |

Curve No. 8 shows the result of exposing the discs to $CaCl_2$ (calcium chloride) in a vacuum, the tank being seldom opened.

Four (4) discs, their average weight being 398.1 grams, were exposed under the same conditions as those discs in Curve No. 9, with the exception that the tank was opened for the first time on the eighteenth day. The operation was continued for twenty-three days, when it was found that the discs had lost on the average less than .1 of a gram since the twentieth day, and the average total loss had been 29.8 per cent. net. From this we assume that the average discs originally held 30 per cent. net of water, which gave a net weight for the discs of 306.2 grams.

Curve No. 9 shows the result of exposing the discs to $CaCl_2$ (calcium chloride) in a vacuum, the tank being opened frequently.

Four (4) discs, their average gross weight being 400.9 grams, were placed in an ordinary powder tank, over and near to, but not in contact with, one thousand (1000) grams of $CaCl_2$ in a round tin pan. The air was exhausted from the tank. Every four (4) days the tank was opened and the $CaCl_2$ dried by exposure in the oven of an ordinary cooking-stove and then replaced in the tank. The discs were weighed whenever the tank was opened. At the end of the twenty-third day, it being very difficult to maintain a vacuum, and the discs having lost less than one (1) gram each since the twentieth day, this plan was discontinued, and it was found that the average loss had been 31.8 per cent. From this we have assumed that the average discs originally held 32 per cent. net of water, as shown by the curve, which gave a net weight for the discs of 303.7 grams.

Curve No. 10 shows the result of exposing the discs to the atmosphere day and night continuously for forty-six days.

Fifteen (15) discs were placed in a 15-inch cubical wooden box upon two shelves that divided the box into three parts. The shelves and sides of the box were pierced with a number of ½-inch holes, in order to allow a free circulation of air. The cover of the box projected on all sides and was made water-tight. The box was placed upon the embankment to the west of the chemical laboratory, where it was partially sheltered by the parapet to the westward. The discs were exposed from the 23d of December, 1884, to the 16th of Feb-

ruary, 1885. During this time they were weighed at short intervals, and six (6) of them found to have become saturated in the violent storms that prevailed. Taking the remaining nine discs, whose average gross weight was 431.8 grams, and assuming that they originally held 31 per cent. net of water, we found that in forty-six days the average loss had been 24 per cent. net, as shown by the curve. The average net weight of these discs, assuming 31 per cent. of water, was 329.6 grams.

The weather average during the forty-six days is shown in the following table:

| Date. | Temp're Noon. | Weather. | Wind. |
|---|---|---|---|
| Dec. 23. | 22 degrees. | Cloudy, but dry. | Westward. |
| " 24. | 23 " | Cold, with snow. | " |
| " 25. | 25 " | Cold and cloudy. | Northward and eastw'd. |
| " 26. | 26 " | Cold and cloudy. | Northward. |
| " 27. | 26 " | Cold, moderating. | Northward and eastw'd. |
| " 28. | [illegible] " | Mild and foggy. | " " |
| " 29. | 44 " | " " " | Southward and westw'd. |
| " 30. | 62 " | Clear and pleasant. | " " |
| " 31. | 45 " | Mild and foggy. | Southward. |
| Jan. 1. | 45 " | Cold and rainy. | |
| " 2. | 23 " | Clear and cold. | Northward. |
| " 3. | 23 " | " " " | " |
| " 4. | 34 " | Cloudy, snow and rain. | |
| " 5. | 41 " | Clear and pleasant. | |
| " 6. | 52 " | Steady rain. | East. |
| " 7. | 45 " | Cloudy and mild. | Southwest. |
| " 8. | 44 " | Clear and pleasant. | Northward and westw'd. |
| " 9. | 52 " | Cloudy, but pleasant. | Southward. |
| " 10. | 30 " | Clear and cold. | Westward. |
| " 11. | 40 " | Cloudy and cold. | |
| " 12. | [illegible] " | Rain. | Southward and westw'd. |
| " 13. | 38 " | Clear and pleasant. | Northward. |
| " 14. | [illegible] " | " " " | " |
| " 15. | [illegible] " | Rain. | Southward and westw'd. |
| " 16. | [illegible] " | " | |
| " 17. | [illegible] " | Cloudy, but clearing. | Southward and westw'd. |
| " 18. | [illegible] " | Clear and cold. | Northwest. |
| " 19. | [illegible] " | " " " | " |
| [illegible] | [illegible] " | " " " | " |
| [illegible] | [illegible] " | Clear and pleasant. | Southward and westw'd. |
| [illegible] | [illegible] " | Clear and cold. | Northward. |
| [illegible] | [illegible] " | " " " | |
| [illegible] | [illegible] " | Stormy, rain and snow. | |
| [illegible] | [illegible] " | Cloudy and damp, little rain. | |
| [illegible] | [illegible] " | Clear and cold. | Northwest. |
| [illegible] | [illegible] | " " " | " |
| [illegible] | [illegible] | Cold and snowing. | |
| [illegible] | [illegible] | Clear and cold. | |
| [illegible] | [illegible] | " " " | |
| [illegible] | [illegible] | Clear and pleasant. | |
| Feb. [illegible] | [illegible] | Rain and snow. | Variable. |
| [illegible] | [illegible] | Clear and cold. | Northwest. |
| [illegible] | [illegible] | " " " | " |
| [illegible] | [illegible] | Cold, damp, foggy. | |
| [illegible] | [illegible] | Cloudy. | Northward. |
| [illegible] | [illegible] | Snow, cloudy, cold. | " |

| Date. | | Tempt'e Noon. | | Weather. | Wind. |
|---|---|---|---|---|---|
| Feb. | 7. | 28 | degrees. | Clear and pleasant. | Northward and westw'd. |
| " | 8. | 28 | " | Cloudy, snow and sleet. | |
| " | 9. | 40 | " | Cloudy and damp. | Eastward. |
| " | 10. | 42 | " | Damp and foggy. | |
| " | 11. | 10 | " | Clear and cold. | Northwest. |
| " | 12. | 21 | " | " " " | Northward and westw'd. |
| " | 13. | 34 | " | Clear and cloudy. | Northward and eastw'd. |
| " | 14. | 28 | " | Clear. | Northeast. |
| " | 15. | 31 | " | Clear and pleasant. | Northward and eastw'd. |
| " | 16. | 34 | " | Overcast and heavy rain. | Southward and eastw'd. |

To ascertain the relative value of the following methods of drying wet gun-cotton discs—viz.: by—first, exposure in a dry room; second, exposure to calcium chloride: *a*, air exhausted; *b*, air not exhausted; third, exposure in steam dryer.

Five (5) discs whose average gross weight was 420.2 grams were exposed for twenty-three days to No. 1, from December 23, 1884, to January 14, 1885, when they ceased to lose weight.

The same discs were placed in No. 2*a* for twenty-two days, January 16 to February 7, 1885, and having ceased to lose weight while thus exposed, were exposed to No. 3 for twelve days, February 9 to 21, 1885; the temperature of the dryer from 9 A. M. to 4 P. M. daily except Sunday averaging ninety-six degrees F.

Five (5) discs whose average gross weight was 420.2 grams were subjected to the same treatment, except that the $CaCl_2$ (calcium chloride) was not in a vacuum. Two of these discs whose average gross weight was 427.5 grams were then exposed to No. 1 for twenty-three days, then to No. 3 for twenty-three days, and finally to No. 2*a* for twelve days.

Two (2) of these discs whose average gross weight was 423 grams were also subjected to the same treatment and in the same sequence, except that the $CaCl_2$ (calcium chloride) was not in a vacuum.

Tabulating the results for comparison, we will have:

AVERAGE WEIGHT OF DISCS AFTER BEING EXPOSED.

| Gross. Av. Wt. | 23 Days Air. | 22 Days $CaCl_2$. | 12 Days Dryer. | Net Wt. Dry. |
|---|---|---|---|---|
| No. 1, 420.2 | 326.46 | 320.93 vac. | 321.3 | 320.93 |
| " 2, 420.2 | 323.18 | 316.9 | 317.67 | 316.9 |
| | | 22 Days Dryer. | 12 $CaCl_2$. | |
| " 3, 427.5 | 336.85 | 331.75 | 331.65 vac. | 331.65 |
| " 4, 423 | 335.65 | 329.15 | 329.35 | 329.15 |

Showing that in every case except the last $CaCl_2$ extracted more moisture than the other methods; also that the vacuum possesses no practical advantage.

The first two cases show that after the discs had ceased to lose weight in the air, they continued to lose when exposed to $CaCl_2$, the loss amounting to nearly 2 per cent. net; and also that the discs, after they had ceased to lose weight by the $CaCl_2$, gained slightly when exposed to the steam dryer.

The last two cases show that after the discs had ceased to lose weight in the air, they continued to lose weight when exposed in the steam dryer, the loss amounting to nearly 2 per cent., and after ceasing to lose weight in the dryer, that when exposed to $CaCl_2$ they lost very slightly in a vacuum, and gained very slightly not in a vacuum.

From this it appears that the same results are ultimately obtained by the use of either steam dryer or $CaCl_2$.

We found that the discs of gun-cotton made at this station contained after final pressure about 15 per cent. net of water; and as it is the custom before packing discs for issue to allow them to remain in an alkali solution for ten (10) minutes, that the discs as issued to the service contain from 30 to 35 per cent. net of water; also that a disc two (2) inches in height contains 315.6 grams of gun-cotton, or about 11.132 ounces avoirdupois.

We consider that of all the different methods pursued to dry wet gun-cotton discs, the following give the best results—viz.: No. 1, exposure to a dry atmosphere; No. 2, exposure to $CaCl_2$; No. 3, exposure in a steam dryer.

The third method will expel the largest percentage of moisture in the least time.

The second method requires twice the time of No. 3 to expel the same percentage of moisture.

The first method, in twice the time required by No. 2, and four times that of No. 1, will still retain at least 2 per cent. of water, which under methods Nos. 2 and 3 would entirely disappear.

Whether it is necessary, in order to obtain complete detonation, that discs for primers should contain less than 2 per cent. of water, we are not at present prepared to state.

The third method requires constant care and attention, a special place, and is attended with more or less risk, which conditions do not commend this plan to the Board for use on board ship.

The first method requires care and a suitable place on shipboard, which conditions can be easily fulfilled. This plan is only available in dry climates, and climatic changes will seriously interfere with it.

The second method requires but little care and attention and is independent of location and atmospheric conditions. The gun-cotton is, while drying, excluded from the action of light, which is to be desired. Calcium chloride ($CaCl_2$) has no effect upon gun-cotton as shown by the analysis appended, except when brought into absolute contact for great length of time (a condition that will never obtain in drying). Although the Board gives the preference to the second (or $CaCl_2$) method, they are of the opinion that both the first (air) and the second ($CaCl_2$) methods should be allowed, and submit the following rules:

## Drying by Exposure in a Dry Atmosphere.

String the discs to be dried on a brass or copper rod or pipe, which should be free from dirt and *oil*; separate the discs from each other to expose all the surfaces freely to the air; suspend the rod in some suitable place—not in the vicinity of the galley or boilers—where the discs will be freely exposed to the air and be under cover (the span of the stern or quarter boat davits, or the spanker boom, with an awning or similar shield over them, will answer the purpose). Expose the discs only when the atmosphere is dry; at other times the discs should be kept in an empty powder tank, which can be kept in the immediate vicinity of the place selected for drying, and kept close to exclude moisture. Weigh the discs every two days, noting the date and weight on the side of the discs with a soft lead pencil. Continue the drying until the discs show no loss of weight for two consecutive weighings, then place the discs in the glass jars, with strips of blue litmus paper between the discs, and treat them according to the rules given for drying gun-cotton primers.

## Drying by Exposure to Calcium Chloride ($CaCl_2$).

This method requires 5 pounds chloride of calcium or calcium chloride ($CaCl_2$), 1 empty powder tank, 3 baking-pans.

Chloride of calcium or calcium chloride ($CaCl_2$) is cheap, and can readily be obtained from any dealer in chemicals. It should not be confounded with chloride of lime or bleaching powder ($CaO_2Cl_2$). The latter has a strong odor of

chlorine, and if used instead of the chloride of calcium ($CaCl_2$) might cause decomposition of the gun-cotton. Chloride of calcium ($CaCl_2$) is odorless and has no bleaching properties.

To distinguish whether the substance has any bleaching properties, stir a small portion in an equal volume of water and immerse a piece of blue litmus paper in the mixture; if the color disappears from the paper when dry (turning white), the substance is chloride of lime or bleaching powder ($CaO_2Cl_2$), and should not be used.

The powder tank can be readily procured on board ship. Care should be taken that it closes easily. The baking-pans should be of such a size that three of them will cover the bottom of the tank when placed alongside of each other, made of stout tin, free from solder, and five to six inches deep. (For the powder tank, model of 1854, these pans should be twelve inches long, four inches wide and five inches deep; this size can readily be entered through the mouth of the tank.)

Divide the calcium chloride between the three pans and place these pans, which should be clean, free from oil or grease, in the oven of the galley and allow them to remain there until all traces of moisture have disappeared from the calcium chloride. Stir the calcium chloride occasionally with a clean metal rod to expose the lower particles. Break the calcium chloride into pieces size of a pigeon's egg. When all traces of moisture have disappeared remove the pans to a dry place and allow them to cool. The calcium chloride should not be put in the tank while warm, or the gun-cotton exposed to it. Place the tank in some suitable location where it will not be disturbed (shaken about), as the calcium chloride may be spilled out of its pans. When the calcium chloride is cooled off place the pans on the bottom of the tank and lay over the pans a copper sieve (tinned copper wire is the best) or the racks from the steam dryer. Then place the discs to be dried on the sieve or racks and close the tank. Open the tank every three or four days, weigh the discs and dry the calcium chloride as before. Mark the weight and date with a soft lead pencil on the side of the discs. Continue this until the discs have ceased to lose weight. While the calcium chloride is drying, the discs can be kept in the tank, which should be closed, to exclude the moisture in the air. When the discs have ceased to lose weight, store them in the glass jars, with strips of blue litmus paper between the discs, and observe the rules laid down for dry gun-cotton primers.

This operation is independent of the conditions of the atmosphere and only requires the care mentioned.

The following experiments were conducted and heat tests made in order to determine the influence of calcium chloride upon the stability of gun-cotton:

Well-prepared gun-cotton will not liberate a trace of acid when exposed to a constant temperature of 150 degrees F. for 12½ minutes. This constitutes the English "heat test."

One disc of gun-cotton was divided into two parts, one of which was packed in a glass jar with fused calcium chloride in such a way that the chloride was in direct contact with and completely covered the gun-cotton; while the other was simply placed in a similar clean glass jar, and after closing both to exclude moisture they were stored in an outhouse for eighty-five days. The gun-cotton at the end of this time showed no external change, and that packed in calcium chloride stood a constant temperature of 150° F. for 21½ minutes before acid reaction was detected; while that stored without the chloride stood the same test for 23 minutes.

One disc of wet gun-cotton was buried in fused calcium chloride contained in a wooden box and stored same as above for ninety-two days. At the end of this time the disc was removed, and a sample gave acid reaction when exposed for 20 minutes to a constant temperature of 150° F.

A sample taken from a gun-cotton disc which had remained for twenty-three days in a vacuum, and over, but not in contact with, calcium chloride, gave

acid reaction after an exposure of 22 minutes to a constant temperature of 150° F.

Another sample, taken from a disc dried same as the last described, except that air repeatedly leaked into the tank in which it was stored, stood heat test for 29½ minutes.

Other gun-cotton discs were dried in a closed powder tank, and over, but not in contact with, fused calcium chloride. The air was not exhausted from the tank, but the chloride was frequently removed and fused. A sample taken from these discs after being stored as above described for twenty-six days withstood a temperature of 150° F. for 20 minutes before acid reaction was observed.

Another sample, taken from discs dried in the same way as the last described, except that the chloride was not fused during the twenty-six days, gave the same results when exposed to the heat test.

A sample taken from a disc that had been exposed to the air for twenty-three days, and afterwards dried over calcium chloride in a closed powder tank for sixteen days, withstood a temperature of 150° F. for 18 minutes before acid reaction could be detected.

A sample taken from a disc dried in the same manner as the last described, except that the air was exhausted from the powder tank, stood the heat test for 17½ minutes. A sample of gun-cotton pulp taken from a well-prepared and well-washed charge was saturated with a concentrated aqueous solution of calcium chloride; after drying, it withstood a temperature of 150° F. for 23 minutes.

Another sample, taken from the same charge and prepared in the ordinary way, gave the same results when subjected to the heat test.

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## BAIRD'S AUTOMATIC STEAM TRAP.

The following is an abstract from the report made to the Bureau of Steam Engineering by a board consisting of Chief Engineers Devalin and McCartney, and Passed-Assistant Engineer Leitch, upon the merits and demerits of a steam trap invented by Passed-Assistant Engineer G. W. Baird, U. S. N., and used on board the United States Fish Commission steamer Albatross:

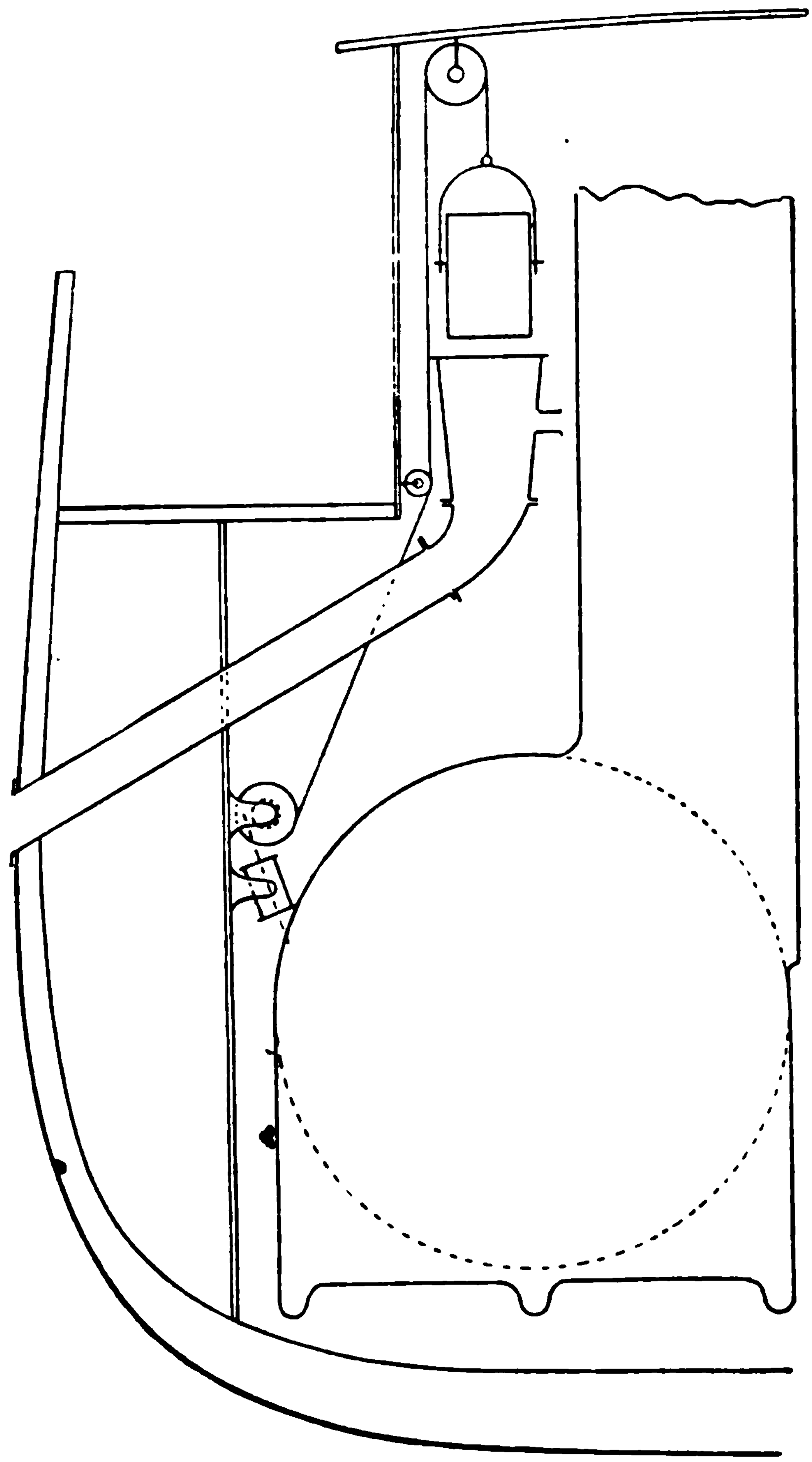
"The trap consists of a cast-iron chamber containing a spherical hollow float, a bell-crank lever and a piston valve. The float is made of glass and is six inches in diameter outside. The inventor does not confine himself to glass, but claims the use of a metal sphere for the same purpose. The piston valve and valve chamber are of brass, and the valve has an opening of one-half of a square inch. The condensed water from the radiators enters the trap on top, and on rising to a given level lifts the float, and, by means of the levers, opens the piston valve for the discharge of the water. When the water level falls to a certain point the valve closes and prevents the escape of steam. There is an attachment for opening and closing the valve by hand. The advantages are: The employment of a piston valve, perfectly balanced, for the discharge; certainty of action; small space occupied; cheapness; lightness; it is automatic; has a large opening for discharge; can be shut off or blown through by the hand attachment. The disadvantages are those common to all traps having closed hollow vessels for floats, which sometimes leak and fill with water, and also that the piston valve will in time become leaky from wear in one direction. We recommend its purchase and use on naval vessels."

W. F. W.

# THE ASH-HOIST OF THE U. S. STEAMSHIP ALBATROSS.

By G. W. BAIRD, Passed-Assistant Engineer, U. S. N.

The demand for a convenient, economical and cleanly ash-chute has existed ever since steam was introduced on board ship. In carrying ashes over the decks, let ever so great care be taken, part will be spilled, which not only soils but cuts and scars the planking. The labor of hoisting the ashes, the loss of time, and the inconvenience to those on deck, are well known, while to those in the fire-room is experienced a still greater annoyance; for, as is often the case, when the fires are cleaned and the ashes ready to hoist, the sailors are at work which is considered more important, and the ashes must wait; with several banks of ashes in the fire-room, it is difficult to get at the fires to stoke them, and, as a result, the steam pressure falls, and the speed of the ship is reduced.



While superintending the building of the Albatross, in 1882, the writer designed a hoist and chute (see Fig.), which was built by the Pusey & Jones Company, which has worked well, and is herein described, with a hope that this or some better arrangement may be utilized in the new Navy. The object of the chute and hoist is to provide simple, effective and economical means of ejecting the ashes without carrying them over the deck. Before describing the device it will be proper to note other machines which have been used in the Navy and abandoned.

The *stand-pipe*, a vertical plate-iron cylinder, was placed in the fire-room of the Neptune in 1863, its lower end being flanged and bolted to the bottom planking, its upper end extending several feet above the water line. Both ends were open. The ashes were dumped into this chute with a copious current of

water, and were washed out through the bottom. It was found on this ship, and on the iron merchant ships using the same device, that the ashes scoured the bottom of the ship in wake of the chute so badly as to wear through the plating in a short time.

A steam ejector was applied on board the Alaska in 1869. The ashes were fed into a hopper, whence they were carried by a steam jet through a chute, passing upward and through the side of the ship. It worked admirably, so far as ejecting the ashes was concerned; but the cinders, moving at such velocity, scoured out the chute in a few days; the cast-iron elbows, where the abrasion was greatest, were increased in thickness up to two inches, which was not sufficient, and the device was abandoned.

"Two hands from each part of the ship man the ash-whip!" was again taken up, and is sung still on board many of our war vessels. If all the men respond except one, the rest will wait for that one and will "growl" until he comes, heedless of emergency. The officer of the deck, with enough else to do, must give his attention and time to this most unmilitary proceeding, if he wants it executed promptly.

The hoist represented in the engraving eliminates these troubles, and though the writer sees details which could be improved, the device has stood the test of time without a single instance of failure. The chute is made of a ten-inch boiler flue, riveted to a flange on the ship's side, and surmounted with a hopper. The chute runs diagonally through the ship's side, and discharges about a foot above the water. A stream of water from a one-and-a-quarter-inch nozzle plays into the hopper.

The engine has an automatic stop which brings it to rest when the bucket arrives at the end of its path.

One man fills the bucket on the fire-room floor and starts the engine to hoist; the other man empties the bucket and starts the engine to lower. The ashes are thus delivered into the sea, about a foot above the load-water line, and they are projected far enough to clear the ship's side at all times. The hopper is covered with a cast-iron lid on a rubber joint. The air in the hopper, above the water entering the chute, must be displaced before any water can enter the ship; so in practice we have not found the rubber joint necessary, and permit the air to come and go past the crevasses under the lid, and we find the weight of the lid is sufficient, in the worst weather, to keep it down without the bolts.

The engine is without gearing; the cast-iron drum, five inches external diameter and twelve inches long, is the crank shaft; a steam cylinder of four and a half inches diameter of bore and seven and a half inches stroke of piston is placed at each end of the drum, with cranks at right angles; the motion of the engine is slow, and although it is bolted to the iron plating of a coal bunker, it is rarely heard on deck. The engine belongs to that class which is reversed by changing its ports, and a single valve acts as throttle and reverse valve.

The Advisory Board adopted this system for the Dolphin, but put a sliding valve at the foot of the chute; the engine they adopted for the hoist is of a different type, but does its work well.

In presenting the plans to the Navy Department for its consideration, the writer enclosed the following testimonial from the commanding officer of the Albatross:

U. S. COMMISSION OF FISH AND FISHERIES,
STEAMER ALBATROSS,
WASHINGTON, *May* 28, 1886.

Captain JOHN G. WALKER, U. S. N.,
*President of Board on Additional Cruisers.*

*Dear Sir:*—I approve and forward the enclosed letter calling attention to the ash-chute in use on board this vessel, and endorse all that Mr. Baird claims for it.

'he time-honored cry of "Man the ash-whip!" or the more modern rattle of

cog-wheels and chain-whip of the ash-hoist are traditions only on board the Albatross, and I trust for the convenience and comfort of the service that this or some equally good device may be introduced into our new vessels.

Very respectfully,

Z. L. TANNER,

*Lieutenant-Commander U. S. N., Commanding.*

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# DISTILLING APPARATUS FOR THE NEW CRUISERS.

The difficulties encountered from the use of mineral oil in steam cylinders, in its distillation from the main boilers on board our ships of war, are aggravated more and more as the boiler pressures are increased. The oil finds its way into the boilers through the condenser, air pump and feed pump.

To completely obviate this difficulty a separate boiler has sometimes been employed, in which clean sea-water alone is used; but in the new ships of war, where it is essential to diminish weight as much as possible, all the boilers must be used, in order to get the regulation two-thirds power; the full power requiring the use of the blast. When a quantity of atmospheric air is introduced into the steam before its condensation, much of the organic matter is oxidized, and may be removed by a special filter. Much of the volatile portion of the oils escapes with the excess of air which is forced into the water, and the remainder finally vaporizes from the tanks or is precipitated. The higher temperatures now used in the boilers are more destructive to the cylinder oils, and make it essential to resort to one of two alternatives—viz.: to use a separate boiler to distil from, or use large tanks which would give the water time to "age." The latter process is out of the question, as neither room nor weight will be accorded for that purpose. Another objection to distilling from the main boilers is that the solid matter in the sea-water (which is a non-conductor), precipitated upon the heating surfaces of the boilers, would soon cause the metal to burn. The thickness of metal in the modern high-pressure boilers is much greater than in the old (low-pressure) boilers, and the transmission of heat through the metal is correspondingly retarded; this is aggravated by the more rapid combustion now employed.

To meet these requirements Passed-Assistant Engineer Baird (the patentee of the fresh-water distiller) has designed an evaporator to take the place of the boiler in his process, which we illustrate.

The coils of the evaporator are of commercial wrought-iron pipe; each coil is in one piece, and there are no joints inside of the apparatus. Steam from the main boilers enters at *A*, and is discharged into the separator. The entrained water is discharged from the separator through *G*, into the hot-well of the main condenser, from *H;* steam is supplied to the donkey pump, which circulates for the distiller (condenser). Thus a circulation is kept up through the evaporator which insures it against "banking up" air, as often occurs in steam heaters.

Sea-water is forced into the evaporator at *J*, the coils being kept nearly covered; this sea-water is vaporized by the heat of the coils; the steam is discharged at *C*, and passes though the aërator *D*, when it induces a current of atmospheric air; and thus the mixed air and steam are delivered to the condenser coils. The condenser coils are made of drawn brass pipes, and are covered with a coating of Banca tin, so that the condensation takes place on a tin surface. Sea-water is kept circulating around these coils (by a circulating pump not shown), and is discharged at *I;* from this discharge—which is warm—the feed supply of the evaporator is taken. The air supplied to the evaporator is conveyed through the pipe *E* from the atmosphere above decks. The condenser is made of brass, the heads three-eighths and the shell one-eighth

of an inch thick; the filter is of galvanized iron No. 22 w. g. thick. The evaporator will be fitted with a salinometer arrangement. It is believed that a constant feed and blow can be so regulated that the apparatus will require but little attention; the pumps and steam connections may all be operated from the engine-room. The evaporator is so designed that the coils may be removed separately for scaling, which will require to be done about twice a year. Considerable weight and space are saved over the old arrangement, and pure water is insured.

| | nament. e Secondary tteries.) | Armor, Side. | Armor, Turret. | Total Estimated Cost. | Authorization. Date of Act. | Remarks. |
|---|---|---|---|---|---|---|
| Puritan.. | | 12" Steel. | 16" Steel. | $2,300,970 | ............ | ............ |
| Mianton | | 7" W. I. | 11½" W. I. | 1,637,110 | ............ | ............ |
| Amphitri | | 7" Steel. | 11½" Steel. | 1,590,930 | ............ | ............ |
| Monadno | | 7" Steel. | 11½" Steel. | 1,592,849 | ............ | ............ |
| Terror... | | 7" Steel. | 11½" Steel. | 1,891,077 | ............ | ............ |
| Armored | Automobile | ......... | ......... | *2,500,000 | August 3, 1886 | ............ |
| do. | Torpedoes. | ......... | ......... | *2,500,000 | do. | ............ |
| *U* | | | | | | |
| Chicago.. | | ......... | ......... | 1,576,854 | 1882 | Twin Screws. |
| Boston.. | | ......... | ......... | 1,031,225 | 1882 | ............ |
| Atlanta.. | | ......... | ......... | 1,031,225 | 1882 | ............ |
| Dolphin.. | | ......... | ......... | 460,000 | 1882 | ............ |
| Charlest | | ......... | ......... | *1,017,500 | March, 1885 | Twin Screws. |
| Baltimor | Automobile | ......... | ......... | *1,325,000 | do. | do. |
| Newark | Torpedoes. | ......... | ......... | †1,300,000 | do. | do. |
| Gunboat | | ......... | ......... | *455,000 | do. | do. |
| do. | | ......... | ......... | *247,000 | do. | ............ |
| Dynamit | ynamite. | ......... | ......... | *350,000 | August, 1886 | ............ |
| Cruiser | ......... | ......... | ......... | †1,500,000 | March, 1887 | ............ |
| do. | ......... | ......... | ......... | †1,500,000 | do. | ............ |
| Gunboat | ......... | ......... | ......... | †550,000 | do. | ............ |
| do. | ......... | ......... | ......... | †550,000 | do. | ............ |
| 1st-Class | ns, 5 Torped. | ......... | ......... | †100,000 | August, 1886 | ............ |
| Stiletto, | ......... | ......... | ......... | 25,000 purchase authorized. | | |
| Floating | ......... | ......... | ......... | 2,000,000 expenditure authorized. | | |

* Contract price for hull and engines only.
† Limit of " " " " " "

# BIBLIOGRAPHIC NOTES.

ALMANACH FÜR DIE K. K. KRIEGS-MARINE. (Issued by the publishers of the Mittheilungen aus dem Gebiete des Seewesens, Gerold & Co., Vienna.)

This little annual, just received, contains, as usual, besides the ordinary matter found in almanacs, a large proportion of useful information, some specially relating to local affairs of the State, and much of general interest, in a compact and readily accessible form.

PART I. contains very complete conversion tables for changing English weights, measures, pressures per square inch, feet per second, etc., into the corresponding equivalents in the metric system. The tables are of daily use to English-speaking people who read the technical papers published on the Continent, and to foreigners who read American and English publications.

PART II. contains tabulated data relating to the guns used by ten principal European powers, and a pictorial diagram showing the armor-piercing power of these weapons.

PART III. has a list, corrected to November, 1886, of all vessels of all descriptions belonging to the governments of twenty-nine countries, the list finishing up with Belgium and Venezuela, each of which has one vessel. With the name of each ship are given the principal data relating to hull, machinery and armament.

We notice several errors in the data relating to the ships of the U. S. Navy. For example: the Lancaster is credited with 2000 I. H. P. and 5 knots speed. This should be 1100 I. H. P. and 9.5 knots. The Alert is given 656 I. H. P., *i. e.* about 100 I. H. P. more than the engines were designed for, and the speed is given as 8 knots, when she makes 10 knots with about 500 I. H. P. Her sister-ship Ranger is also given 656 I. H. P., but only 6 knots instead of 10. (The errors in the I. H. P. of the two latter ships were probably copied from "King's War Ships," etc., 1881, but the corresponding speeds (10½ knots) there given were not copied.)

PART III. has also a table showing the number, rank, grade, etc., of officers and men attached to each ship in commission in the Austrian Navy.

PART IV. is entirely taken up with the tables of pay, allowances, commutations of quarters and pecuniary compensations for every conceivable accident or incident of service, and pensions of all descriptions, all arranged in a most elaborate system; and, we must add, apparently just to a degree. The officers, line and staff, are divided into classes according to rank, and the pay and allowances, etc., regulated for these classes. The compensation appears small; but if, as in the English service, the age of officers is so much less for a corresponding rank than in our Navy, the aggregate pay received by an Austrian officer would compare favorably with ours.

PART V. contains the list of officers in the service, with rank, etc., as in our Naval Register, and also designates those who have received special honors, decorations, medals, etc.—a feature which might be introduced with advantage in our Annual Navy Register, where an officer who has received the thanks of Congress is not distinguished in any way from the others, and one who has gained rank by gallant conduct is put down in the same way as his neighbor on the list who has reached his position by simply doing routine duties.

W. F. W.

## AMERICAN INSTITUTE OF MINING ENGINEERS, TRANSACTIONS.

FEBRUARY, 1887. Valuable article on magnesium carbonate as a non-conductor of heat.

The following table presents the results of experiments made :

| Description of the 2-inch Pipe Covering. | Diameter in inches. | Weight per ft. in ounces. | Thermal units conducted per lineal ft. per hr. |
|---|---|---|---|
| 1. Hair-felt, wrapped with twine, burlap jacket. | 4½ | 12½ | 69.02 |
| 2. Sectional carbonate of magnesia, asbestos paper jacket, bands. | 4½ | 20¼ | 75.29 |
| 3. Sectional carbonate of magnesia, canvas jacket, bands. | 4½ | 20¼ | 75.68 |
| 4. Sectional mineral wool, asbestos paper, mineral wool, muslin. | 5¼ | 28¾ | 76.68 |
| 5. Chalmer-Spence Co.'s covering, asbestos, hair-felt, paper. | 4½ | 28¼ | 82.95 |
| 6. Shields & Brown's covering, asbestos paper, sheathing paper. | 4½ | 27¼ | 84.65 |
| 7. Reed's covering, asbestos paper, felt paper. | 4¼ | 26¾ | 89.62 |
| 8. Fossil meal pipe covering, fossil meal, organic fibre. | 3¾ | 24 | 114.54 |

W. F. W.

## ANNALEN DER HYDROGRAPHIE.

PART X., 1886. Cyclones in West Australia, March, 1882, and January, 1879. Cruise of the German squadron under command of Rear-Admiral Knorr along the coast of New Mecklenburg and New Hanover, and thence to Hong-Kong. Hydrographic notes on the island of Longa-Longa, east coast of Africa. Remarks on the harbor of Constantinople. Influence of the sun and moon on the trade-wind. On avoiding collisions at sea by placing the side lights at an angle of 45° with the top light. Meteorological and hydrographic notes.

PART XI., 1886. Measurement of the rise and fall of water. Cruise of the German corvette Albatross through the Caroline Islands. Reconnoitring cruise of the German corvette Habicht on the west coast of Africa. Meteorological and hydrographic notes.

PART XII., 1886. Measurement of the rise and fall of water (concluded). Hydrographic notes and sailing directions for the Bismarck Archipelago. Current between the Mediterranean and the Black Sea. New method of finding course and distance in great-circle sailing. Meteorological and hydrographic notes.

## ANNALEN DER HYDROGRAPHIE UND MARITIMEN METEOROLOGIE.

15TH YEAR, 1 VOL. Thunderstorms, and observations for the same by Professor F. G. Hahn. Hydrographic observations taken by H. I. M. S. Olga on her voyage through the Bismarck Archipelago from Meoko to Nusa and thence to Matupi. The Empress Augusta

River, Emperor William's Land. Remarks about Montevideo and Charleston, S. C. Contribution to the theory of coast-currents and counter-currents. Deep-sea soundings on the coast of Nova Scotia and Newfoundland (U. S. S. Albatross). Deep-sea water bottles with deep-sea thermometers. Prediction of a chronometer rate, by Prof. D. Börgen. Report of temperature-coefficient of chronometers kept in the observatory of Wilhelmshafen during the winter 1885 and 1886. June rains in Japan, 1885 and 1886, by E. Knipping, Tokio. Notices, hydrographic tables.

ANNALEN DER HYDROGRAPHIE UND MARITIMEN HYDROGRAPHIE.

15TH ANNUAL SERIES, 2D VOLUME, 1887. About thunder-showers and observations therefor (conclusion), Dr. F. G. Hahn. Tourabaya and its mercantile relations, by Commander H. I. M. S. Adler. Hydrographic notes for the Marshall Islands, by Commanders H. I. M. SS. Bismarck and Albatross. Notes about Colachel and St. Helena, by Captain Herndorf, German barque Werner. Notes from the voyage of the German ship Herrman, Kingston, South Australia. Observations for temperature of the ocean on the route Hamburg, London, Lisbon and Southwest Africa. Deep-sea soundings, North Atlantic Ocean (U. S. S. Essex). Typhoons in the China Sea. September typhoons of 1886 in Japan. Influence of magnetic forces on the rate of chronometers. Small notices. Tables.

ENGINEER.

DECEMBER 24, 1886. Comparison of English and French Navies, together with list of all the armorclads belonging to each. Trial of the submarine torpedo boat Peacemaker at New York City.

This boat is propelled by a 14 I. H. P. steam engine, with a Honigmann fireless boiler, and made a successful trip in the Hudson River for half an hour under the surface, descending as deep as 40 feet, and describing various curves. There were three persons on board, and the air remained reasonably pure, making it probable that the voyage could have been continued for several hours. It is claimed that the boat can maintain a speed of 8 knots per hour, for several hours, with one charge of caustic soda in the boiler.

Editorial on liquid fuel, pointing out in detail the difficulties yet to be overcome before such fuel can come into general use on board ship at sea.

JANUARY 7, 1887. Torpedo vessels in Europe.

| | No. | Tons. | Cost in £. |
|---|---|---|---|
| Great Britain, | 156 | 23,902 | 1,460,000 |
| France, | 143 | 20,450 | 1,253,000 |
| Germany, | 150 | 14,597 | 900,000 |
| Russia, | 115 | 5,104 | 312,000 |
| Italy, | 89 | 7,966 | 500,000 |

Many of the English boats are 38 to 40 metres in length, but the French only 25 to 30 metres.

JANUARY 14, 1887. El Destruidor, torpedo cruiser.

The vessel is a twin-screw cruiser, 200 feet long, 25 feet beam, 13 feet depth, built of high-tension steel. Every piece of steel or iron in her is galvanized. She has a ram-bow and a bow-rudder, the latter partly to assist manœuvring, and partly to act as a lee-board when under sail. The stern-rudder is of a new type known as Thompson and Biles's "patent sternway manœuvrer," with a surface of 80 square feet, and is considered an improvement on the ordinary balanced rudder, and has the advantage of giving more complete control of the vessel when going full speed astern. The steering gear works both rudders and the capstan. There are 39 water-tight compartments. The engines are in two separate compartments and the four boilers in four, and the whole surrounded by coal bunkers. The engines are triple-expansion, and the boilers locomotive of 3800 H. P., with air pressure of 2¼ inches. The consumption of coal on a four-hour trip was only at the rate of 2.1 pounds per I. H. P. per hour, showing that the vessel could steam at full speed for about 700 knots. At 11½ knots she could go 5100 knots. There are three masts, made to hinge down and fitted with fore and aft rig. There are two bow and one stern torpedo tubes, and two broadside tubes to be fitted on the upper deck. There are one 9-cm. pivot gun on the forecastle, four 6-pounder rapid-firing broadsides, and two 37-mm. Hotchkiss forward. [illegible]

FEBRUARY 11. The Nordenfeldt submarine boats for Turkey.

These boats have two functions: 1st. To steam at the surface; 2d. Underneath. In the first case the two cylinder engines get steam from a boiler fired in the usual way. The armament consists of two 1-inch Nordenfeldt guns. In the second case, when it is desired to sink, water is let into three ballast tanks, one at each end and one amidship, the two former holding about 15 tons and the latter about 7, until nothing but the glass conning-tower is visible. While the tanks are filling, the furnaces are closed to put out the fires, and the piece of funnel connecting the boiler with the outboard opening in the vessel's side is removed and the opening closed. Steam is now taken from a storage reservoir holding about 30 tons of water previously heated by steam from the boiler until its vapor has a tension of 150 pounds. This, with the vacuum, is sufficient to drive the boat 30 or 40 miles. To sink lower there are two screws on vertical shafts, one at each end of the boat. There are two movable fins at the bow to assist in controlling the movement of the boat under water. The action of all three screws is regulated by the captain from the conning-tower. The data of the Turkish boats are: Length, 100 feet; beam, 12 feet; displacement, 160 tons; I. H. P. 250, with 100 pounds steam; coal capacity, 900 knots at moderate speed. The details of the torpedo armament have not been disclosed.

Firing trial of the 110½-ton B. L. Elswick gun, with illustration of the gun, etc. The Mougin disappearing turret (illustrated).

W. F. W.

ENGINEERING.

DECEMBER 24, 1886. Trial of the submarine torpedo boat Nautilus in the Tilbury docks.

The boat is cigar-shaped, 60 feet long and 8 feet diameter, with total displacement of 52 tons. There are two Edison-Hopkinson motors supplied from 180 Elwell-Parks storage cells, each of about 4 H. P. hours. The boat was tried successfully at slow speed in the dock, on the surface, and below water, and performing various evolutions. It descended to a depth of 28 feet (measured from top of boat to surface). Expected speed 8 to 10 knots, and revolutions 750. It is intended to carry 6 men, and the air contained in the boat is found sufficient for a two-hours' trip without renewal or purification.

JANUARY 7, 1887.

The second-class steam cruiser Thames, of the Amphion class, made her contractor's trial of the engines on Tuesday. Draught forward, 13 feet 5 inches; aft, 17 feet 3 inches; steam, 97 pounds; revolutions, starboard 108, port 110; total I. H. P., starboard 2166, port 2329; speed, 17 knots.

The Allan air-spring pressure gauge; sketch and description with latest improvements. New Russian cruisers.

The Russian Government is reported to have decided to construct six more vessels of the Vitiaz and Rinda class. They are 265 feet long, 45 feet beam, and 14 and 18 feet draught fore and aft. Compound engines 3600 I. H. P., and speed 16½ knots; can steam 3500 knots at 14 knots, 5000 at 13 knots, 5750 at 12, and about 10,000 knots at 8 or 10 knots per hour. Armament, ten 6-inch rifles, eight Hotchkiss, and four 4-pounders; also Whitehead torpedoes and two torpedo-cutters 32 feet long, armed with Baranovsky guns.

Fire boats. Paper read before the American Society of Mechanical Engineers, by Mr. Wm. Cowles, Engineer, N. Y. (Member of Naval Institute, and late Assistant Engineer, U. S. N.).

Three pages working drawings and page of data relating to five fire boats built in this country and England, designed by himself and others in the United States and in England.

FEBRUARY 4. Clyde shipbuilding and marine engineering for 1886.

The most notable feature in this connection is the extraordinary extent to which the triple-expansion engine has been adopted, both in war ships and the merchant marine. Almost every screw steamer sent out of the Clyde shipyards last year was fitted with this kind of engines. The total output amounted to upwards of 170,000 I. H. P., besides a number of comparatively new compound engines altered to triple-expansion.

Messrs. Denny & Co. have satisfactorily proved that the practical adoption of the principle of quadruple expansion in marine engines is attended with even a still greater economy. Some engineering firms are scarcely yet disposed to go beyond steam pressure of 140 pounds per square inch in boilers working triple-expansion engines, but with Messrs. Denny & Co. 160 pounds is now quite common. Their quadruple-expansion engines, now building, are designed for working up to 170 to 180 pounds pressure. Such engines with 180 pounds pressure are no new thing on the Clyde. The engines of the yacht Rionnag-na-Mara (already described in this journal), built at Greenock, have given excellent results. On trial, with 180 pounds pressure and twelve expansions, the coal consumption was only 1⅛ pounds per I. H. P., best Welsh coal. On a cruise of 3638 knots, with steam sometimes as low as 145 pounds, the consumption of coal of mixed average quality did not exceed 1.43 pounds per I. H. P., including coal used for steam for steering gear and windlass. The use of mild steel both for forgings and castings in engine construction is one of the most marked features in marine engineering practice at the present day. During the year was built the torpedo vessel El Destruidor, which on trial reached the speed of 23 knots, the greatest ever yet attained by any steam vessel with full equipment on board. The improvements that have been going on during the past few years in ship construction and marine engineering, especially since the introduction of steel, have neither been few nor unimportant. Such plant as is now in use in the best-equipped establishments renders it possible to manipulate plates and angles for hulls with such rapidity that it is now possible for a vessel of almost any dimensions to be built and fitted out ready for sea within a period of twelve months. There is no doubt that the

Clyde shipyards and engine shops are now in a condition of remarkable efficiency, owing to the development which has taken place in labor-saving appliances of almost every kind.

FEBRUARY 11. On seagoing torpedo boats; urging the importance of seaworthiness in torpedo boats. W. F. W.

FRANKLIN INSTITUTE JOURNAL.

MARCH, 1887. The microscopic structure of iron and steel, by F. Lynwood Garrison, F. G. S.

INSTITUTION OF CIVIL ENGINEERS, LONDON.

VOL. LXXXVII, 1886-87, Part I. The discussion of electric-light houses.

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION.

NO. CXXVII. French operations in Madagascar, 1883-1885, by Captain S. Pasfield Oliver, late R. A., F. R. G. S. Barnett's patent water brakes, by Mr. Frederick Barnett, C. E. Colonel Mulock's patent for driving punkahs, by Colonel T. Edmonds Mulock, C. B. Coast defense, by Colonel Schaw, R. E., Deputy Director of Works for Fortifications. Small arms for field artillery, by Major J. D. Douglas, R. A. B. F. T.

JOURNAL DU MATELOT.

NO. 5, FEBRUARY 6, 1887.

On the 20th of January there was launched at La Seyne the first of fifty of a new class of torpedo boat. It was commenced in 1886. Its number is 99. The principal dimensions of this little boat are: 115 feet long, 11 feet wide, 8 feet deep. Its displacement is, with everything on board, but 54 tons; this includes crew, bunkers filled, and four automobile torpedoes. Two of these torpedoes are placed in the launching tubes, whose height above the water-line has been raised 15 inches to facilitate launching the torpedoes in rough weather. The two other torpedoes are kept in reserve. These torpedo boats will attain a speed of 20 knots, and must maintain this speed for three consecutive hours during the trials, which will take place in fine, clear weather. According to a special correspondent this boat sits well in the water. The commanding officer's post is well sheltered from the sea. The machinery was tried January 21, and the boat started on a cruise January 29. The two first trials have given great satisfaction.

NO. 6, FEBRUARY 13, contains an account, with illustrations, of a boat-detaching apparatus designed by M. Rees.

A paragraph says: "The torpedo-boat exercises at Toulon will commence April 1st, 1887, and will continue six weeks."

LE YACHT.

DECEMBER 11, 1886. P. 448: Plan of seagoing torpedo boat building for Chinese Government, with partial description. P. 449: Picture of the English Polyphemus. Commences an article entitled

"Studies on the American Navy," being extracts from and comments on the writings presented to the U. S. Naval Institute. This number dwells upon Admiral Simpson's able article.

DECEMBER 18. P. 453: "Studies on the American Navy," taking up the papers of Lieutenant Calkins and Ensign Rodgers.

DECEMBER 25. P. 463: Trial of El Destruidor, Spanish torpedo boat. P. 465: "Studies on the American Navy," reviewing the papers of Commander Hoff, published in 1884. A memoir on naval tactics, by Lieutenant-Commander Elmer, 1884, and Commander Taylor's paper of March 17, 1886.

JANUARY 1, 1887. P. 4: The submarine vessel Nautilus—plans and description.

JANUARY 8. P. 9: "Studies on the American Navy"—end.

The article is finished with these complimentary words: "May these imperfect outlines and summaries attract the attention of the French public to the publications of an association so competent as the U. S. Naval Institute. We have but just touched upon a very small number of the articles emanating from its members, but all the others give equal evidence of conscientious research and are filled with original views which are generally to the point."

P. 14: The fighting Navy of Russia. P. 15: Plans of the Russian ironclad Catherine II.

JANUARY 15. P. 18: Explosive projectiles. P. 21: Picture of the Gabriel-Charmes, type of a new class of single-gun gunboat constructed at La Seyne.

JANUARY 22. P. 27: Double-screw seagoing torpedo boat, constructed by Thomson, on the Clyde, for the Russian Government. Plans, views and description thereof.

JANUARY 29. P. 36: Illustration—Le Déroulède, French seagoing torpedo boat built at Havre.

FEBRUARY 5. P. 44: Plans of new U. S. vessels. P. 45: Jury rudder, by Captain Swan, of San Francisco.

FEBRUARY 12. P. 51: Launching of the ironclad Pelayo, built at La Seyne for the Spanish Navy.

FEBRUARY 19. P. 60: Elevation and plans of the Pelayo, with a general description.

FEBRUARY 26. P. 65: The canal from Paris to the sea.

MARCH 5. P. 75.

The following ships will be commenced this year for the French Navy: Three cruisers of the Dupuy de Lôme class, 4162 tons each; three cruisers of the second class, 3000 tons each; three cruisers of the third class, type Surcouf, 1877 tons each; eight contre-torpilleurs, type Ouragan; twenty-four torpedo boats first class.

P. 80: Contrasting the principal Transatlantic lines—Cunard, German Lloyd, and French line.

MITTHEILUNGEN AUS DEM GEBIETE DES SEEWESENS.

VOL. XIV., NOS. 9 and 10. Atmospheric electricity and the weather, by Captain C. von Bermann. Review of Admiral Freemantle's article on naval tactics. Rapid-firing cannon. Reorganization of the Spanish Navy. New Schichau torpedo boats for China and Italy. Steam-steering-apparatus torpedo boats. The French Navy—trial of the Duguesclin. Sea torpedo boat Ouragan. The Turkish Navy. The Danish turret ship Iner Hvitfeldt. The 110-ton gun for the Benbow.

With these numbers appears a description of the cruise of the Austrian corvette Saida in the Atlantic and Pacific Oceans in the years 1884–1886. This report contains full and authentic information in regard to the exports and imports of the places visited. The information is of importance to the service as well as to business men.

NOS. 11 and 12. Budget of the French Navy for 1887, and the 140,000,000 credit of Admiral Aube. Rules for handling the machinery and boilers of the Schichau torpedo boats. The Russian Navy. The English Navy—armored cruisers Australia and Undaunted. A new submarine torpedo boat. New cruisers for the Chinese Navy. Description of the trial of the Russian torpedo boat Wiborg. The French Navy—first-class cruiser Alger. The Medford cannon.

NORSK TIDSKRIFT FOR SOVAESEN.

NO. 3 of 5TH ANNUAL SERIES. Naval tactics (conclusion); compilation from English, French and Italian works on the same subject. Bursting of the guns on board H. M. S. Collingwood, by Premier Lieutenant G. March. Electric log of Commandant Fleuriais; from the French, by Premier-Lieutenant E. Steenstrup. On carrying petroleum in bulk on board steamers; from the *Nautical Magazine*. Lecture before the "Sea Military Society" (Naval Institute), by Com.-Captain Wisbeck, upon "the history of the development of great guns in navies during the years 1860 to 1870." After treating that subject, a treatise on the same subject for the Swedish Navy follows. Reviews of foreign articles: Le Tonnant, garde-côtes cuirasse (French) Puragang, torpedo boat (*Mittheilungen aus dem Gebiete des Seewesens*); brown powder from Rhenish Westphalia Powder Co. (*Deutsche Heereszeitung*); electric boat from *Iron*; electric life buoy.

Sinking of the steamer Oregon. Foreign notes: New French cruisers. Chinese torpedo boat; the Spanish Navy. Official Miscellany.

Memorial of Commander Henrik Jacob Müller. Sea tactics. Theory of the Bremms slide-valve gear. Classification of the French fleet. Equinoctial storms. Foreign notes: American torpedoes; the English armored ship Benbow; the German swift-dispatch boat Greif; experiments with English armored ship Resistance. New submarine boat. Official miscellany. W. F. W.

PROCEEDINGS OF THE ROYAL ARTILLERY INSTITUTION, WOOLWICH.

FEBRUARY, 1887. The protection of heavy guns for coast defense, by Captain G. S. Clarke, R. E. The Nile expedition of 1885, lecture by Colonel F. Duncan, C. B., M. P., R. A. The attack formation of infantry, by Lieutenant-Colonel G. B. Macdonell, R. A.

REVUE DU CERCLE MILITAIRE.

No. 4, DECEMBER 25, 1886. The organization of columns of attack having in view the destruction of obstacles accumulated by the defense.

VOL. II., No. 1, JANUARY, 1887. Report by General Berthier on the duties of the general staff, Army of the Alps, 1796. End of article on organization of columns of attack. Trial of Nautilus, submarine boat, in the East India docks, London.

Dimensions, 62 feet long, 8.6 feet greatest diameter, being shaped like a cigar. The motive-power is an electric engine of 45 H. P.; speed, 19 knots.

No. 2, JANUARY 8. Conclusion of General Berthier's report; also a description of new equipments for foot soldiers in French Army.

No. 3, JANUARY 15. The velocipede in the Army.

No. 4, JANUARY 23. An article on the new instructions (for an engagement) given to the German infantry, containing general principles for the offensive; school of the soldier, of the company, of the battalion and of the regiment. There are many interesting articles in this number under the heading "Chronique militaire," such as: The new German repeating rifle; Schichau's torpedo boats; the Schulhoff repeating rifle, and the official programme of instructions for the troops of different corps of the Italian Army for the summer manœuvres of 1887.

No. 5, JANUARY 30. Complete detail of the new Spanish fleet.

No. 6, FEBRUARY 6. Account of trial of Nordenfeldt submarine torpedo boat at Constantinople.

No. 7, FEBRUARY 13. Rules regulating the use of the repeating rifle in the German Army, dated February 3, 1887. The new German Army equipment for foot soldiers. Trial of a torpedo boat at Trieste.

It is stated that a speed of 23 knots was obtained, and that by making some changes a greater speed would be developed.

No. 8, FEBRUARY 20. Description and pictures of new French knapsack. The manœuvres of the German fleet, August and September, 1886, giving the names of vessels composing divisions. The 110-ton and 68-ton guns.

No. 9, FEBRUARY 27. The Italians at Massouah, giving plans and description. The fortifications on the Meuse rendered necessary by the change in artillery.

NO. 10, MARCH 6. The defenses of the English colonies.

Japan has ordered 150 automatic torpedoes from Schwarzkopf, and ten 34-centimetre and twenty 12-centimetre guns of Krupp. An opinion by a Russian general on the inconvenience of the repeating rifle. D. H. M.

REVUE MARITIME ET COLONIALE.

JANUARY, 1877. Description of the Province of Battambang. The Legion of Honor (continued). Submarine navigation applied to the defense of ports. Historical studies of the French Navy (continued). The budget of the English Navy (continued). Naval chronicle.

FEBRUARY, 1887. Oyster culture in 1886. Report upon the gyroscope-collimator. The Legion of Honor (continued). The cyclones in the Gulf of Bengal. Historical studies of the French Navy (continued). Description of the Province of Battambang (conclusion). The Scotch fisheries in 1886. The budget of the English Navy (conclusion). Naval chronicle.

MARCH, 1887. The Austrian expedition to Jan-Mayen Island. Determination of the deviation of the vertical line upon the coasts of France, and its effect upon the determination of the time. The Legion of Honor (continued). Appendix to the article on the movement of the top. Naval chronicle. B. F. T.

RIVISTA MARITTIMA.

NOVEMBER, 1886. The cruise of the Vettore Pisani (continued). Navigation notes: The Galapagos Islands to Callao, Callao to Honolulu, Honolulu to Manila. The Italian Navy estimates (continued). Plans and descriptions of the four U. S. cruisers authorized by act of March 3, 1885.

RIVISTA DI ARTIGLIERIA É GENIO.

JANUARY, 1887. Note on a formula of penetration derived from experiments made at Metz.

$S$ is the area of the circle of perforation, $\chi$, $\beta$ two constants depending on the substance; then $p = S.a\ (1 + \beta v^2)$. R. C. S.

REVISTA MARITIMA BRAZILEIRA.

AUGUST and SEPTEMBER, 1886.

On the 23d of last July there was made in England the first trial of the submarine torpedo boat invented by the distinguished American engineer Ericsson. It was made at Milford Haven, under direction of Second-Lieutenant Gladsone, of the gunnery school-ship Vernon. The boat is 9.14 metres long, and threw a projectile of one ton weight. The first trial was made at a depth of 3.35 metres, and the projectile traversed a distance of about 155 metres. The inventor thinks it possible to obtain a range of 300 metres if necessary. W. F. W.

Notes of travel. The binocular sextant. Naval tactics. Organization of the meteorological service in Europe. Modern artillery.

The torpedo. Miscellaneous notes: On the use of oil for calming the sea; the Inconstant, French dispatch boat first class; foreign seamen in England; the Popoffkas; the Ericsson submarine boat; the Italian fleet; the English naval and military manœuvres at Milford Haven. Necrology. Notices to mariners.

REVISTA DE MARINA (VALPARAISO).

NOVEMBER, 1886. Routine on board H. M. ships (British). The torpedo question (concluded). Data, hydrographic, commercial and administrative, relating to our ports, etc. Lunar distances. The Society Islands, Tubnaï and Rapa. Means of preventing syphilis among the crews of the naval vessels of the Republic. Naval prize essay. Decision of the judges. On the reorganization of the *personnel* of our fleet in all its branches. Some thoughts concerning ships with armor belts. The Esmeralda. Notes: The Orlando, belted cruiser; trials of the Italia, Italian armorclad; electric steering apparatus (Washburn system); the Orion (Spanish torpedo boat); movements of the ships of the Fleet. W. P. W.

The 111-ton guns were fired for the first time on board a ship and caused no damage whatever to the machinery. After this the engines were tried, and the speed obtained was 13.5 knots with 12 boilers, and 17.1 knots with 26 boilers and 85 revolutions. Temperature in fire room 72° C.

Subsequently the trials were ended in the latter part of May, 1886, and a speed of 18 knots was obtained, but could only be maintained during the first hour of the trial. The mean speed for the rest of the time was only 17.8 knots. Instead of 96 revolutions, only 89 were obtained, and the calculated I. H. P., 18,000, was not developed. W. F. W.

TRANSACTIONS OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

NOVEMBER, 1886. Valuable article on the high-pressure hydraulic system of distributing power in cities, etc., showing the advantages of this over other systems in certain cases. W. F. W.

UNITED SERVICE GAZETTE.

JANUARY 15, 1887. A new torpedo. Vexed questions in naval construction.

JANUARY 22. Machine guns in the field. Autumn manœuvres.

JANUARY 29. Naval strategy.

The British Government has, it is stated, consented to lend six gunnery instructors to the Chinese for the period of three years, with the option of the renewal of their services at the end of that period, should they be required. These are not the only British naval officers lent, or to be lent, to the Chinese Government. They are only additional, and are specially employed for instruction in gunnery.

FEBRUARY 5. Armed cruisers.

The torpedo boat catcher, built by Messrs. Thomson, of Clyde Bank, Glasgow, for the Spanish Government, made the run from Falmouth to Cape Finisterre in 24 hours, the mean speed being 21 knots. The vessel is 450 tons

displacement, and is propelled by two sets of three-cylinder engines, each in separate compartments. She carries several guns and has five torpedo tubes. Two rudders, one forward and one aft, have been fitted, to enable her to manœuvre quickly.

FEBRUARY 12. Coast defense by gunboats.

FEBRUARY 19.

As serving to show the activity in the Russian Navy at present, it may be mentioned that Messrs. R. Napier & Sons, of Glasgow, have just shipped for the armorclad Sinope, 10,150 tons, building at Sebastopol, the largest set of triple-expansion engines that have yet been made for a man-of-war. They are designed to indicate 12,000 horse-power without forced blast. The same firm have also dispatched three sets of triple-expansion engines, to indicate 2000 horse-power each, for gunboats building at Nicolaieff. At the Motala works the engines are being constructed for three other gunboats building at Sebastopol, while a fourth is being built and engined at Copenhagen. The Tchesme, a sister ship to the Sinope, has been launched, and the engines, of the compound type, are being fitted on board by Cockerill, of Belgium. Another battle ship like the Sinope, the Catherine II., is well advanced at Nicolaieff, the machinery for which will be supplied from the Baltic works, at St. Petersburg.

FEBRUARY 26. Magazine and repeating arms.

MARCH 5. Naval intelligence department. Hints on practical electric working.

MARCH 12. Serious naval scandal. Admiralty contracts. Prussian field artillery. The Navy estimates.

The final proof experiment with the first of the great guns for the Benbow was made at Woolwich on March 9, with complete success, two projectiles, each weighing 1800 pounds, having been fired with a charge of 1000 pounds of powder behind each. The projectile was discharged with an initial velocity of 2128 feet per second, and after the two shots the gun was found to be uninjured. This gun weighs 111 tons, and is the largest piece of ordnance ever fired in England. The carriage weighs 95 tons. The calibre is 16¼ inches, and the total length 44 feet. The gun is fired by electricity. On March 12 Captain Fitz-Gerald. R. N., lectured, at the Royal United Service Institution, on "Mastless Ships of War." The lecturer advocated immediately unrigging the present ironclads, leaving them only military masts.

MARCH 19. *Personnel* for submarine mining. The Navy estimates.

The estimated cost of building the new belted unarmored cruiser soon to be begun at Chatham Dockyard is £92,000, of which sum £29,000 will be expended in wages alone. The new vessel, which is intended to steam at 20 knots an hour, will, it is expected, be completed and launched during the present year. The Camperdown, a vessel of the central-citadel type, 330 feet long, 68 feet 6 inches beam, 10,000 tons displacement, had her contractor's trial, with natural draught, at Spithead on the 14th of March. The ship was under steam soon after 9 A. M., but full power was not developed until quarter to ten, when the patent log was hove overboard to check the result of her six hours' steaming, while the vessel was put on the first of her runs at the mile in Stokes's Bay. The Camperdown on this occasion drew 22 feet 3 inches forward and 24 feet 5 inches aft. (When all ready for sea, it is estimated that she will draw 26 feet 3 inches forward and 27 feet 3 inches aft.) The motive-power of the ship consists of two sets of three-cylinder vertical inverted compound engines in two separate compartments actuating twin screws. The steam in her boilers showed a pressure of 83.3 per square inch, while the vacuum in the starboard engines was 28.33, and in the port engines 28.29, and the revolutions

94.41 and 95.38 respectively. The indicated horse-power of the combined engines varied from 8500 to 9103, giving a mean total horse-power of 8605.94. The consumption of coal during the trial was at the rate of 2.11 pounds per horse-power per hour. The ship had four runs in Stokes's Bay, completing the first mile, which was with the tide, in a little over three minutes, or at a speed of 17.73 knots per hour. The second mile was run at the rate of 15 knots against the stream; the third at 17.30, and the fourth at 15.78—a mean rate of 16.30 knots for the four runs, which was considered very satisfactory. On the termination of the mile test, the vessel had a four-hours' continuous steam trial in the Channel, off the Isle of Wight, to the Needles and back. The machinery worked capitally all the time, the patent log at 4.15 P. M. registering a distance of 112 miles, traversed in the six and a half hours the vessel had been under steam. During the trial water troughs were tried under the stokeholes to check the fusion of the metal bars where much heat is developed, according to the plan used in the new torpedo boats. The telephone was also tested as a means of communication with the engine room. On March 16 the Camperdown was tested at continuous steaming and at the measured mile with forced draught. The ship drew 22 feet 4½ inches forward and 24 feet 4½ inches aft. She first had her four-hours' consecutive steam test, being at the end of this put on the measured mile, and finally experiments were made in turning, the vessel answering her helm with the utmost readiness and going about almost in her own length. With 88 pounds of steam in her boilers, and a vacuum of 26.93 in the starboard engines, and 27.43 in the port, there was a mean high pressure in the respective engines of 38.58 and 46.97, the low pressure in the same being 19.93 and 20.47 respectively. The number of revolutions per minute was 101.85, and the collective indicated horse-power 11,740.86. This is considerably above the rate contracted for, and everything that could be desired. The power developed from the engines realized a mean speed under forced draught of 17.144 knots, and under natural draught of 16.6 knots. The machinery worked easily and smoothly throughout all the trials, and the heat in the stokeholes was not excessive during the time of the forced draught, although the consumption of coal averaged 3.26 pounds per horse-power per hour. It is expected that the Camperdown will be ready for service about the end of next year.

B. F. T.

UNITED STATES NAVAL INSTITUTE,

ANNAPOLIS, MD., *April* 22, 1887.

At a meeting of the Board of Control of the United States Naval Institute the following resolutions were adopted:

*Resolved,* That by the death of Lieutenant John W. Danenhower, U. S. Navy, late Secretary and Treasurer and a member of the Board of Control, the Naval Institute has lost an officer whose fidelity, energy, and ability, in the discharge of the duties of his office, contributed in a large degree to the present prosperity and usefulness of the Institute.

*Resolved,* That Lieutenant Danenhower's character commanded the esteem and confidence of the members of this Board, and that the unvarying courtesy of his manner, the kindness of his disposition, and the generous qualities of his manhood endeared him to his associates as a friend.

*Resolved,* That the members of the Board of Control offer their respectful and profound sympathy to the family of the deceased.

By direction of the Board of Control.

P. F. HARRINGTON,
*Commander, U. S. N.,*
CHAIRMAN.

CHAS. R. MILES,
*Lieutenant, U. S. N.,*
SECRETARY.

## NOTICE.

Owing to an unavoidable delay in receiving the decision of the judges, it has been deemed advisable to print the Prize Essay, without discussion, in the present number of the Proceedings.

The meeting for the discussion of the Essay at Annapolis, Md., will be held on October 14, 1887. The Corresponding Secretaries will hold meetings at their respective Branches for the discussion of the Essay at any convenient date, not later than October 14th. Members not able to attend any of the meetings may take part in the discussion by forwarding their remarks in manuscript to the Secretary and Treasurer, or to the Corresponding Secretary of any Branch, not later than October 13, 1887.

All MSS. of the discussion must be forwarded from the Branches to the Secretary and Treasurer before October 20, 1887.

By direction of the Board of Control.

CHAS. R. MILES, *Lieut., U. S. N.,*
*Secretary and Treasurer.*

NEW YORK, *May* 19, 1887.

SECRETARY, NAVAL INSTITUTE, ANNAPOLIS, MD.

*Dear Sir:* After examination of the five essays upon the Naval Brigade, submitted to us for decision, we have the honor to state that we consider the essay bearing the motto "In hoc signo vinces,"* entitled to the prize.

In our opinion the remaining essays stand in the following order of merit:

First—"He who can get more from his men than can his opponent from his, is always at an advantage." † Deserving honorable mention.

Second—"Aut nunquam tenta aut perfice." ‡ Deserving honorable mention.

Third—"J'ai pris mon parti."

Fourth—"Necessity is the mother of invention."

Respectfully submitted,

J. S. SKERRETT,
*Captain, U. S. N.*
CHARLES HEYWOOD,
*Major and Brev. Lt. Col., U. S. M. C.*
J. W. MILLER.

* By Lieut C. T. Hutchins, U. S. N. † By Lieut. T. B. M. Mason, U. S. N.
‡ By Ensign Wm. Ledyard Rodgers, U. S. N.

THE PROCEEDINGS

OF THE

UNITED STATES NAVAL INSTITUTE.

Vol. XIII., No. 3. 1887. Whole No. 42.



PRIZE ESSAY FOR 1887.

"*In hoc signo vinces.*"

# THE NAVAL BRIGADE: ITS ORGANIZATION, EQUIPMENT, AND TACTICS.

By LIEUTENANT C. T. HUTCHINS, U. S. Navy.

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CONTENTS.

## I.—ORGANIZATION.

To be successful in the landing of seamen and marines and in the operations on shore of the naval brigade, much will depend upon the previous system of organization and training of the personnel that will compose the force. The fact must not be lost sight of, that upon the amount of work in the care and preparation of the seaman to meet the requirements of detached service will his efficiency be measured.

To fulfill the demands of a hastily assembled fleet, with battalion organizations sometimes very dissimilar, and to unite the different ships' battalions into a homogeneous military force for landing, must, under the most favorable circumstances, prove a difficult task.

There has been, and probably always will be, some objection by naval men to the naval brigade and the landing of sailors for operations on shore. The legitimate sphere of the seaman being afloat, the landing of a naval force cannot be otherwise than incidental to the service. Any attempt to organize a ship's company with the infantry battalion as a basis would probably result in confusion and

disaster; to return to the days of the Invincible Armada and fill our ships with soldiers would be folly.

Under our system of government and the growing opposition to a large standing army, it must be apparent to the most conservative that the naval brigade is a pressing necessity.

The demand for landing parties from our ships and fleets, both at home and abroad, was shown during the labor riots in this country in 1877, at Alexandria, Egypt, in 1882, and more recently on the Isthmus of Panama in 1885. The organization and transportation to the Isthmus of Panama of a naval force in April of that year demands more than a passing notice. As a measure of quick despatch, economy, and the efficient work performed, the accomplishment of the desired results on this occasion was more than satisfactory, and a progressive and enterprising people like ours will never fail to lend support to a force which with the least expenditure of time and money accomplishes the desired work.

We still find some opposition on shipboard to-day among sailors to being landed as infantry; the growing and constant desire to turn the sailor completely into a soldier at these times, and his invariable opposition to this transformation, is the cause of want of success and lack of interest. But this opposition of the sailor may be easily overcome by judicious treatment, emulation, and a system of competition, not only between companies in ships' battalions, but between different ships; and with this interest once awakened, the regular landing day would be hailed with delight. No valid reason is apparent why the naval brigade should interfere with great guns or the marlinspike, if we stop what is known in the Navy to-day as show drills, theatrical in their effect and forced on the Navy by long custom. The absolute niceties of the soldier should be abolished in the drills of the ship's battalion. The time devoted to these unbusiness-like evolutions should be employed to some useful purpose, and the sailor not subjected to the strait-jacket drill every infantry day. Every ship's battalion should be landed frequently when in port, authorities and weather permitting. Once a week would not be too frequent for a cruising ship, and the brigade should be landed for several days in succession when the Admiral assembles his fleet for drill and inspection.

To land the naval brigade in opposition to well-organized and trained forces of infantry would not be expedient, but that a naval force would prove more than a match for any but regular soldiers

none can doubt. For street fighting, the trained seaman may be considered quite equal to the regular soldier. The economy of time in the transportation of a naval brigade along the seaboard or on our large rivers, thus avoiding any opposition a force would meet with in having to pass through cities to destination by rail, and its being ever ready, must make such a force always a desirable one. What sailors can accomplish when landed to co-operate with an army was well illustrated during the Franco-Prussian war, by the French seamen at the siege of Paris as artillerymen, and at Le Bourget as infantrymen. England, with her small standing army, has of late years placed great reliance upon her naval brigade. The conduct of her sailors and marines in the Ashantee war of 1873, and in Egypt and the Soudan in 1884, merits the greatest praise. One of the most brilliant exploits of a naval force was the landing of the naval brigade of the French fleet and taking of Sfax in July, 1881, when the electric light and the 1-pound Hotchkiss shell gun, mounted in ships' boats, were brought into use.

The Watch, Quarter, and Station Bills now supplied to all our naval vessels, call for a battalion with an officer to command called "Colonel Commanding," also other necessary officers. The battalion is composed of, first, the artillery, with an officer to command, each piece being in charge of a junior officer with a quarter gunner. Then follows the marine guard, forming the first company; next, the seamen forming the other companies, and last, the pioneers. This arrangement appears to work fairly well in the service, though in some vessels there are ammunition passers and carriers, and stretchermen to care for the wounded.

The term naval brigade is now applied to the battalions of two or more ships brigaded together for the purpose of landing for operations on shore. In uniting the different battalions under one head, each ship's battalion should land and fall in together; no separation of the companies of a battalion should be allowed if it can be avoided. In forming the brigade for exercise and drill, the music should form on the right of the line; then should follow the artillery battalion; next in order the first battalion of infantry, made up of the first company of marines, "Co. A," the second company of marines, "Co. B," etc.; then the second battalion of infantry, made up of the first company of sailors, "No. 1" company, the second company of sailors, "No. 2" company; next, the third battalion of infantry, and so on; and, last, pioneers and stretchermen—bearing in mind that all the

artillery of the force are to be kept together, as well as the companies of marines and the companies of sailors. Any division or breaking up of the full companies of marines, or of the companies composed of seamen of a ship's battalion, should not be thought of; men that are known to each other should be allowed to go into battle together and under their own company officers.

The great feeling of pride in one's own ship should be cultivated to the fullest extent, hence the necessity of keeping ships' battalions as intact as possible. In naming the companies, it will be seen that the marines have their companies distinguished by letters and the sailors their companies by numbers, which numbers in a ship's battalion are the same as those of their respective divisions, No. 1 company coming from the first division, and so on. Again, a numbered company would indicate that the company was composed of seamen.

A company of infantry should be composed of 40 men, with 2 guides, 2 file-closers, and 2 ammunition passers and carriers — in all 46 men. Companies should not be too large and unwieldy; large companies could only be a question of economy of officers, and in this matter no navy to-day can afford to be wanting. A division should, if possible, furnish a company of infantry, except the master's division; and the company should be commanded by the division officer, one of the junior officers of the division being associated with him. In small ships this may not be at all times possible, but when unable to do so, the engineer's division would be merged in the powder division. The high-powered breech-loading rifle and rapid-firing cannon worked by small gun's crews must necessitate an increase in the number of men, and greater intelligence in the powder divisions of our ships, if they are to be efficient; servants and bandsmen will have to be eliminated and better men must take their places: therefore, with a more capable and much larger powder division, one infantry company could be selected from it in large ships. The chief aim must be to have the companies commanded by their own division officers, with whom they are familiar as well as known.

Too much stress cannot be laid upon the fact that the hasty assembling of a naval force for landing, under strange officers to command, can be but ill-advised. Officers should know the men who are to serve under them, and this can only be accomplished by organizing the force under the officers of the ships to which the men belong and to whom they are known. The commander of the naval

brigade and his staff could come from any station or ship, but the company officers should come with the men from the same vessel. A writer on the naval expedition to the Isthmus of Panama in April, 1885, complains of the difficulty encountered under the present system of transfer papers in the selection of good men to fill ratings, especially in an emergency such as the hurried fitting out of an expedition. It will be seen that this difficulty can be avoided by landing men under command of the officers of their own ships. For another writer on the same subject, speaking of the landing of the naval brigade of the North Atlantic Squadron at Gardiner's Bay in August, 1884, with officers and men from the same vessels, says: "It was noticeable that the sergeants and corporals chosen from the *petty officers* and *leading men* performed their duties with intelligence and force. Another fact was apparent: the men who were most distinguished as *seamen* were, as a rule, more prompt and exact in their duties on shore."

In every ship's battalion of two companies of infantry and one company of artillery there should be allowed four ammunition passers and carriers, four pioneers—composed of one blacksmith, one armorer, one carpenter, and one fireman—two stretchermen, one bugler, and two signalmen, with a bayman allowed to the medical officer. On drill days two markers and one drummer will land with the battalion; markers and drummers are of no use whatever in actual service, and should not be taken.

*The officers of the ship's battalion* would be as follows:

An officer (the Executive) to command battalion.
Company officers.
Adjutant.
Commissary, who will also act as Quartermaster.
Surgeon.
Gunner, with large battalions.
A Junior Officer, when Gunner is not allowed.

[illegible] commanding officer of the naval brigade should do his utmost [illegible] a band; nothing adds so much to the pleasure of the men, [illegible] more to make them contented and cheerful. The band [illegible] armed with rifles and drilled; there are too many non-[illegible] on shipboard at the present day, and the sooner an effort [illegible] do away with this state of affairs the better for the service.

I unhesitatingly say that the powder division, engineer's force, music, and all servants, except perhaps the stewards and cooks, should be drilled in the use of the rifle; more particularly in the firings, loadings, and facings. A company of artillery should consist of 16 men, and the men selected for the pieces should come from the larger pivot guns or master's division; preferably the first four men from the latter, if they are accustomed to work and fight these guns on shipboard. The divisional officers from the pivot guns command the sections, junior officers the pieces.

The landing of artillery should generally be limited to the 3-inch breech-loading rifle, the Hotchkiss revolving cannon, the single barrel Hotchkiss, and the Gatling. Smooth-bore howitzers have had their day and they should not be landed. The guns should be manned by large crews, capable of taking with them plenty of ammunition. Too many guns should not be landed, as they hinder the movements of a force and are always a heavy burden. A naval brigade that is thoroughly organized and trained needs but few pieces of artillery. It can be said that we have arrived at that state in the Navy when we are unable to say just how many pieces of artillery should be landed. It would seem far better to land a few guns with large crews and plenty of ammunition; care being taken to keep similar guns together, so as to avoid confusion with the ammunition. Ammunition boxes and wagons should be painted the same color as the gun carriages and limbers, and they should also be numbered. It must be remembered in landing artillery that the nature of the service will always be a great consideration, as well as the difficulties to be encountered in transportation of ammunition for the rapid-firing cannon. All the artillery should have limbers, when 7 additional men would be added to each of the gun's crew, making a crew up to 23 men for gun and limber.

By reducing the number of guns and increasing the number of men in the crews, adding limbers to each gun to carry the large amount of ammunition now required, more efficiency will be gained, and about the same number of men would be landed in a ship's battalion. In small ships one piece of artillery should be landed with the battalion, in the larger ones two pieces. In combining the battalions of a fleet and forming the brigade, more guns would be found than necessary; but as the crews of two guns combined form one company, they could be landed as such if desired, from those ships that would under ordinary circumstances land two pieces of artillery with limbers.

The ordnance manual already requires that the crews of the howitzers and machine guns shall be united so as to form an infantry company and be drilled as such. At the present time, vessels in our service do not land men often enough as infantry. More arms should be supplied to vessels, and one company be selected from each of the powder and engineer's divisions in large ships, and in small ships one company from the two divisions combined. Then in a vessel of the Atlanta class we would have from the crew 2 companies, 92 men, and two guns and limbers, 46 men, 4 pioneers, 4 ammunition passers and carriers, 2 stretchermen, 2 signalmen, and 1 bayman, in all 151, out of a complement of 242 men, not including the marine guard, which would probably land 37 men, making a total of 188. After landing so large a number of men from a vessel of the Atlanta class, there would be left on board 3 men belonging to the marine guard, 26 men belonging to the main battery, 13 men belonging to the secondary battery, and 52 men belonging to the powder and engineer's division combined, total 94 men; a force, with the modern improvements on ships, still large enough to fight and work the vessel. One company of infantry would come from the main battery, one company from the powder and engineer's division combined, and two companies of artillery from the secondary battery, the men from the secondary battery being accustomed to work the machine guns.

The landing of so many men may be considered an innovation on the practice of the service, but it will be seen that the circumstances governing the work required of the ship during the absence of the battalion would decide if all of the force or a certain number of companies should be landed. If the artillery is landed without the limbers, large gun's crews would still be required to carry the ammunition for the machine guns. Still the necessity must be apparent to every one that both the howitzer rifles and machine guns should be fitted with limbers. The men selected to work the machine and rapid-firing guns should be carefully and well drilled, noted for their high standard of intelligence, coolness under fire, and specially alert; the first five men of the crew should be good marksmen, equally well trained. They should be armed and able to defend their guns in the event of a jam occurring in the mechanism and the enemy coming to close quarters. Care should be taken that the ammunition is not separated from the guns, and that guns of the same kind are kept together. Some of the machine guns of the English Naval Brigade in the Soudan failed at the most critical moment, and the failure of

the machine guns in the French army during the Franco-German war was due to the want of men thoroughly trained in their use. The value of the machine gun cannot be overestimated, when it is properly served; and to serve the gun with any degree of success, constant and frequent drills must be carried on and the rapidity of fire determined by practice. Cartridges sometimes hang fire, and in the presence of an enemy, under excitement, fast firing might be a source of great danger; no pains should be spared in the instruction of the seamen in target firing, the most important of all drills in the Navy.

Combining the units, the ships' battalions, and forming the brigade, we would find, say with a force of twenty companies of infantry: ten pieces of artillery, total infantry 880 men; artillery, 230 men; there would be 40 ammunition passers and carriers, 30 pioneers, 25 stretchermen, 10 buglers, 8 signalmen, 1 master-at-arms or 1 ship's corporal, 15 cooks when in encampment, and 3 apothecaries. It will be seen that 10 pioneers have been eliminated in the combination, also 5 baymen and 12 signalmen. These men could be drawn from to fill vacancies, or be used to carry camp equipage, ammunition, and handling rations and stores, the signalmen leaving their kits behind; or they could be turned over to the beach-master at the landing place of the brigade.

The apothecaries and stretchermen, and they alone, are to care for the sick and wounded; and it must be impressed on the minds of the men that they are never to leave the ranks in battle to assist the wounded. Apothecaries, baymen and stretchermen, with the medical officers, are the non-combatants. Two medical officers should be allowed to the brigade, one being on the staff. An officer should be detailed as signal officer. One gunner would have charge of the ammunition for the infantry, and another of the ammunition for the artillery. A gunner or gunner's mate should be sent with every ship's battalion when landed. The gunner's mates, pack animals, ammunition, and ammunition carts, if provided, should all be under the command of a capable and energetic commissioned officer. Pioneers on the field of battle will assist the ammunition passers, and when the supply of ammunition is exhausted, both they and the ammunition passers and carriers should be ordered to take a rifle and cartridges from any wounded men and join the fighting line. To fill casualties among the ammunition passers and carriers, their places should be filled by men selected from the companies to which they belong. Two carpenters should be detailed with the pioneers.

*Marines.*—The legitimate duties of the marine corps being those that pertain to soldiering, their organization, equipment and tactics should be all that can be desired. The guards of most vessels being of necessity very small, the combination of two or more is required to form an infantry company, which should be, if possible, numerically the same as a company of seamen. Signal being made, the different guards would be organized into companies with their officers on convenient ships of the assembled fleet, and landed in separate boats pulled by sailors. The companies of marines should be as near like the companies of seamen in their organization as circumstances will permit. Allowing 5 companies of marines in a brigade of total 25 companies of infantry, the 10 pioneers that have been eliminated in the combination could be detailed as ammunition passers and carriers, and 5 baymen as stretchermen.

The total force of marines—5 companies—would be 220 men rank and file, 10 ammunition passers and carriers, 5 stretchermen and 5 buglers.

*Officers.*—One officer of suitable rank to command battalion.

Adjutant.

One Aide.

Five Captains of companies.

Five Lieutenants of companies.

*Intelligence Staff.*—Much attention should be given to obtaining information of the movements, plans, and the number of the enemy. To obtain all possible information without the enemy being aware of the fact is a great point gained in actual warfare.

An Intelligence Staff, selected, if desired, from the intelligence officers of the fleet, should land with the brigade. When an expedition is fitted out and sails from the United States, this staff could come from the Naval Intelligence Office, Washington. This staff should be composed of two officers with their outfit and necessary assistants, their strength depending very much upon the mission they are to fulfill. They should come under the immediate command of the Adjutant General of the brigade or Chief of Staff. Their duties must not be confounded with the duties of the signal staff, the work of the latter pertaining more to keeping up constant communication between reconnoitering parties and the main body, or between the main body and fleet. No matter how small the force, an intelligence er should accompany the landing party. The great necessity for

such a staff was shown at Alexandria, Egypt, during the bombardment of that city by the English fleet, 1882, and more particularly after the landing of the English naval brigade.

The frequent preparation of the English landing force for a threatened attack, and unreliable information as to the movements and whereabouts of the enemy, very much crippled their force thrown on shore there to protect the city, costing loss of life and very considerable loss of property by fire.

*The Field and Staff Officers* of the naval brigade should be as follows:

An officer of suitable rank to command the brigade.
An officer to command each battalion, and one aide.
Brigade Staff.—One Adjutant General (also Chief of Staff).
One Ordnance Officer, who also acts as Military Engineer.
One Quartermaster and Commissary.
One Signal Officer.
One Surgeon.
Two Aides to commander of brigade.
Intelligence Staff.—Two officers.

*Sanitary Precautions.*—In spite of science and modern inventions to destroy men in battle, the fact still remains that disease carries off more men than all other causes together. No pains should therefore be spared to provide for the proper treatment of the sick and wounded. When not in the presence of an enemy, the first consideration in pitching a camp should be sanitary conditions of the ground.

A code of instructions guarding against prevalent diseases, and emanating from the senior medical officer of the brigade, should be followed as closely as possible. Men should sleep in their shirts and drawers, their shoes, stockings and outer clothing being removed. In throwing up entrenchments and bivouacking on new-made ground, the health of the officers and men will be greatly increased if they have something to sleep on. The ventilation of tents should be carefully attended to and no crowding be permitted. When in encampment, tents should be struck frequently in fine weather to allow the sun to dry the ground occupied by them. No orders preventing men from committing nuisances in camp can be too strict. In entering on an expedition, if possible, such seasons of the year should be selected as will favor the health of the men; and it would be well to bear in

mind the frequent moving of the brigade to new camping grounds. A very liberal supply of medicines and food should be provided for the sick and wounded.

It cannot be doubted for an instant that we are sadly in need of transport vessels for use of both the Army and Navy. After the landing of a naval force from transports, the vessels could be used as a base of supplies and for hospitals.

In the *preparation of orders* for the brigade the following points should be well considered, the commander of the brigade defining the duties and responsibilities of each officer, and his subordinates:

1st. Object of expedition and probable length of time on shore.

2d. Number of each arm of the service, infantry and artillery, to be landed.

3d. Rendezvous for boats.

4th. Map of "order before landing," with the position of each boat and covering vessel marked thereon.

5th. Number of covering vessels.

6th. Name of ordnance vessel, hospital ship, provision ship.

7th. Number of artillery boats to assist to clear beach and not to land.

8th. What articles each boat is to carry.

9th. Number of days' provisions men are to carry.

10th. Number of battalions and by whom commanded.

11th. Officer to command at beach.

12th. Number of rounds of ammunition that each man is to carry.

13th. Amount of spare ammunition required.

14th. The distance of objects on shore from the beach, for use of covering vessels and artillery boats.

15th. Order of formation of the line of battle on shore.

16th. What men are to carry, provisions, ammunition, clothing, etc., and what articles are to be left in the boats.

17th. If spare ammunition, water, stoves, etc., are to be landed from covering vessels or to be kept in boats at landing.

18th. If entrenchments are to be thrown up by beach-master, and if he is to have any of the heavy guns landed for armament.

19th. State of tide, depth of water, and the nature of the bottom.

The commanding officer of the brigade should receive his orders in writing from the admiral, or senior officer present, or when an expedition sails from the United States, from the Secretary of the Navy; but he should not be hampered by instructions and petty details in mer case.

The battalion commanders and the beach-master should receive their orders or instructions from the commander of the brigade, through the chief of staff, or adjutant general, and in no other manner.

## II.—Equipment.

The equipment of sailors landed from our ships for operations on shore should not be a matter of individual whim or fancy. There should be no sparing of criticism until we have attained uniformity in the combination of the guns' crews and the battalions of a fleet of vessels meeting even for the first time. The breech-loading magazine rifle, with which every naval brigade should now be equipped, brings before us the problem of the supply of ammunition to the fighting line.

Firings will begin at longer distances, and with the continued advance at the most critical moment the men may be without ammunition; to guard against such a catastrophe will be one of the most difficult services required of us. To meet this requirement a considerable force will be wanted to carry and pass ammunition, which can only be attained by reducing the size of the infantry companies. On an extended march horses and wagons would have to be pressed into service, when the ammunition passers and carriers would make up the ammunition train, converting any wagons obtained into ammunition wagons. A small wagon, fitted for one horse, and also with a drag-rope, the wheels being the same as those for the artillery wagons, should be furnished each ship in the service that would land two companies of infantry and one piece of artillery. This wagon would be used for the transportation of extra ammunition, mess gear or camp equipage. Ammunition passers and carriers will always be a necessity, either to carry ammunition on the march or to supply the fighting line in battle. There appears to be a considerable difference of opinion as to how the naval brigade should be armed, but the weight of authority would seem to favor arming every man with a rifle that could carry one. In the artillery companies the first 7 men of the guns' crews should be armed with large-size navy revolvers of the latest pattern. Cutlasses should be discarded, as they are of no earthly use; the remaining men at the gun should be armed with rifles. Should limbers be landed with guns, 13 men would go with the gun and 10 men with the limber. In fitting limbers for the artillery the wheels should be exactly the same

as those for the gun carriage, being interchangeable; all wheels to have broad treads, that they may be serviceable in sandy and marshy ground. The first 3 men of each limber's crew are to be armed with revolvers and the others with rifles, all rifles to be fitted with slings to go over men's backs. In case of a jam in the mechanism of a piece which would render it liable to be taken by an enemy, the riflemen would be prepared to prevent a capture. By introducing light shields the fighting power of the artillery might be improved. Shields weighing about 5 pounds to the square foot could be fitted to the gun carriages, and admit of easy transportation. Pioneers will be armed with large-size navy revolvers, and carry implements for entrenching and cutting road-ways. Every man armed with a rifle, except men belonging to the artillery, should carry 80 rounds of ammunition. In the artillery the men armed with rifles will carry 40 rounds, and those armed with revolvers 60 rounds of ammunition.

Two orders of marching will be used in this paper, *Light Marching Order* and *Heavy Marching Order*. I have given the amount of ammunition to be carried by the latter; the former would carry half of this amount, as seen in the accompanying tables. These two "marching orders" should be used throughout the service, and the articles to be carried in each should be specified in the orders of the fleet, that it may be known on each ship how her battalion is to be equipped on receiving a signal to land.

Officers should be armed with a sword and revolver—large size—though it may be a question open to discussion if the days of the former are not numbered. The sword as a badge of office may serve its purpose, but for actual war it is a useless appendage. An improved magazine gun fitted with slings, and not too heavy, would be very useful for all officers of companies.

The sword bayonet is too heavy and clumsy; a light, well-made bayonet should be supplied. Cartridge boxes, belts, and pouches for carrying ammunition should have straps to support them from the shoulders; when not supplied, the straps can be made on shipboard of canvas, crossed at the back like suspenders. The handiest belt now in use for carrying cartridges is the Mills web belt, which seems to answer every purpose in the Army, when the one that is worn around the waist is fitted with shoulder straps. Extra belts can be filled with cartridges and packed away in canvas bags to be served out in an emergency. The emergency having passed, they would be turned in again. These extra belts should be worn over the left

shoulder. Every officer and man should carry a blanket; the men's blankets should be rolled in a canvas or waterproof sheet strapped together and slung over the left shoulder and retained there by a loop. Rolled in the blanket should be a woolen shirt, a pair of woolen stockings, and a towel.

There is no reason why men should not be furnished with light canvas knapsacks for carrying blankets and clothing; experience teaches us that without them there is little comfort either in the camp or on the march. Canteens should be carried by every one; if unable to obtain them, common bottles covered with canvas and fitted with slings will carry sufficient drinking water. Every man will carry a mess pan, pot and spoon slung to his belt or in his knapsack.

Ships' sails and the boats' sails make very good tents; capstan bars, boats' masts and oars being used for tent poles. For a prolonged stay on shore, application for tents to be supplied from the Army would be better; though there is no reason why each vessel in the Navy should not carry several tents instead of so many useless and spare sails.

The ammunition passers and carriers should be equipped each with two canvas bags, one worn over each shoulder; the bags containing 100 rounds of ammunition each, and weighing 11 pounds; this would give 22 pounds weight to each carrier. Should no pack animals or carts be available for the spare ammunition, large ammunition bags would be required, each one capable of holding two of the smaller bags—200 rounds. These large bags will be strapped with leather, each strap having two loops or rings, through which should be run poles; the poles should also have wide straps a short distance from the ends to go over the carriers' shoulders, and of the proper length to permit them to be grasped by the hands. The total weight for two men to carry would be 46 pounds (400 rounds of ammunition). Ammunition passers and carriers are not armed. Buglers and signalmen will be armed with rifles fitted with leather slings. Signalmen will also carry kits. All the medical force should wear the red Geneva cross and carry a flag (white with red cross), to be displayed from any field hospital or building that may be in use. None of the force will be armed except the medical officers, who will wear their swords only. The master-at-arms and ship's corporal will be armed with the navy revolver and carry 20 rounds of ammunition each.

*Dress.*—Officers' dress should be the uniform blouse; underneath the blouse a strap should cross the body, passing over the right

shoulder to support the sword: woolen shirt, blue trousers, and brown leggings fitted with a lacing—buckles are a nuisance.

The head-dress for both officers and men should be the uniform cap, and in hot climates the helmet and canvas hat: a curtain to shade the back of the neck would also be useful. Every one should wear brown leggings that come well above the calf of the leg so that they cannot slip down. White short leggings may look well on drill, but in active service they are liable to slip down when wet, and they also make a good target for the enemy.

The new white canvas hat now issued to the men should be dyed brown for active service on shore. Everybody should have two undershirts and two pairs of socks—underclothing and stockings should be of wool—woolen stockings are indispensable on the march. If necessary, officers should provide themselves with overcoats and the men with pea-coats; and each should have a piece of painted canvas or waterproof sheet to sleep on. When tents are carried, a ship's tarpaulin thrown on the ground makes an admirable bed. When transportation can be obtained, officers' and men's effects could be carried in ship's bags that will keep out the water: one bag to an officer, and one to every three men, the latter messing and sleeping together.

Officers and men should bear in mind that any white articles of dress are conspicuous marks and are sure to draw the fire of an enemy's riflemen.

The brigade commander and staff should be mounted, if horses are obtainable, as also the commanding officers of battalions and staff. When the brigade is under fire all mounted officers would dismount.

Gun-cotton or some kindred explosive should be supplied to ships, and issued to the landing force for the purpose of blowing up buildings, furnished in 20 or 25 pound kegs, with outfit for firing. In the defense of buildings, or of an entrenched position hastily taken on landing—anticipating an attack—by placing several kegs of explosive material at the points most likely to be assailed, great assistance would be given to the defense. Gun-cotton was used with good effect at Alexandria, Egypt, by the English naval brigade to destroy buildings and prevent the spread of the terrible conflagration that raged after the bombardment of that city in July, 1882; and the attempt of the American fleet to land powder in tanks and [illegible]t through the streets with burning buildings on either side was [illegible]ccess—in point of fact, the attempt was abandoned.

*Armed Cars.*—It may frequently occur that armed railroad cars can be made use of by landing parties, such as flat cars fitted for carrying light guns, with boiler plates and sand bags for the protection of the crews.

When a force is landed to occupy a city, or no march is contemplated, 100 rounds of ammunition should be carried by the infantry, and 80 rounds of revolver ammunition by the artillery.

## Weight of Articles carried by Men.

### Infantry.

### *Light Marching Order.*

| | Pounds. | Ounces. |
|---|---|---|
| Waist-belt, bayonet and scabbard | 3 | 12½ |
| 40 cartridges | 3 | 14 |
| Rifle (Lee magazine, long barrel) | 9 | |
| Haversack and two days' rations | 5 | 15¾ |
| Canteen, filled | 4 | 4¼ |
| Pot, spoon, pan, knife | 1 | 4 |
| Blanket roll, containing one undershirt, soap, towel, comb, one pair stockings | 4 | 11½ |
| Tobacco | | 3? |
| Total | 33 | 1 |
| Articles worn by Infantry (weight) | 7 | 8 |

### *Heavy Marching Order.*

| | Pounds. | Ounces. |
|---|---|---|
| Waist-belt, bayonet and scabbard | 3 | 12½ |
| One belt, over left shoulder | 1 | |
| 80 cartridges | 7 | 12 |
| Rifle (Lee magazine, long barrel) | 9 | |
| Haversack and two days' rations | 5 | 15¾ |
| Canteen, filled | 4 | 4¼ |
| Pot, spoon, pan, knife | 1 | 4 |
| Blanket, rubber poncho, towel, soap, comb, one undershirt, one pair stockings, pea-coat | 11 | 13¼ |
| Knapsack | 2 | 2½ |
| Tobacco | | 3? |
| Total | 47 | 3¼ |
| Articles worn (weight) | 7 | 8 |

### ARTILLERY.

#### *Light Marching Order.*

| | Pounds. | Ounces. |
|---|---|---|
| Waist-belt, revolver and 40 cartridges | 4 | 12 |
| Haversack and two days' rations | 5 | 15¾ |
| Canteen, filled | 4 | 4¼ |
| Pot, spoon, pan, knife | 1 | 4 |
| Blanket roll | 4 | 11½ |
| Accoutrements | 2 | 4 |
| Tobacco | | 3? |
| Total | 23 | 6½ |
| Articles worn (weight) | 7 | 8 |

#### *Heavy Marching Order.*

| | Pounds. | Ounces. |
|---|---|---|
| Waist-belt, revolver and 60 cartridges | 5 | 6 |
| Haversack and two days' rations | 5 | 15¾ |
| Canteen, filled | 4 | 4¼ |
| Pot, spoon, pan, knife | 1 | 4 |
| Blanket, rubber poncho, towel, soap, comb, one undershirt, one pair stockings, pea-coat | 11 | 13¼ |
| Knapsack | 2 | 2½ |
| Tobacco | | 3? |
| Total | 31 | 0¾ |

### RIFLEMEN WITH ARTILLERY.

#### *Light Marching Order.*

| | Pounds. | Ounces. |
|---|---|---|
| Waist-belt, 20 cartridges | 4 | 5¼ |
| Rifle (Lee magazine, short barrel) | 8 | 12 |
| Haversack and two days' rations | 5 | 15¾ |
| Canteen, filled | 4 | 4¼ |
| Pot, spoon, pan, knife | 1 | 4 |
| Blanket roll | 4 | 11½ |
| Tobacco | | 3? |
| Total | 29 | 7¾ |

#### *Heavy Marching Order.*

| | Pounds. | Ounces. |
|---|---|---|
| Waist-belt, 40 cartridges | 6 | 4¼ |
| Rifle (Lee magazine, short barrel) | 8 | 12 |
| Haversack and two days' rations | 5 | 15¾ |
| Canteen, filled | 4 | 4¼ |
| Pot, spoon, pan, knife | 1 | 4 |
| Blanket, rubber poncho, etc | 11 | 13¼ |
| Knapsack | 2 | 2½ |
| Tobacco | | 3? |
| Total | 40 | 11 |

Thirteen men of each artillery company are armed with rifles, but without bayonets.

*One hundred men* would require the following rations for two days on shore: a total of 465 pounds 10 ounces, divided as follows, each man carrying 1 pound of pork, cooked, 1 pound of beef, cooked, 2 pounds of bread, 4 ounces of sugar, 2½ ounces of coffee, 4 ounces of beans, cooked. Total, 4 pounds 10½ ounces per man.

*Strength of a naval brigade* of 20 companies and 10 pieces of artillery:

1 Brigade commander.
*Infantry*—12 Field and staff officers.
40 Officers of companies.
1 Passed Assistant Surgeon.
1 Gunner.
2 Carpenters.
880 Rank and file.
40 Ammunition passers and carriers.
30 Pioneers.
25 Stretchermen.
10 Buglers.
8 Signalmen.
1 Master-at-arms, or
1 Ship's corporal.
3 Apothecaries.

One officer to command at place of landing of brigade called Beach-master, with three officers to command the divisions of boats at landing.

The master-at-arms or ship's corporal will have charge of all the mess outfit and one mess kettle for each company.

*Artillery*, 10 guns—4 Field and staff officers.
5 Officers of sections.
10 Junior officers.
1 Gunner.
230 Men.

Should no limbers be supplied, the crews would be reduced to 16 men for each piece of artillery, making a total of 160. In this event the other men, 7 in number, from each crew would be required to carry ammunition.

*Pioneers* will be armed and equipped as follows (Light Marching Order):

| | Pounds. | Ounces. |
|---|---|---|
| Waist-belt, revolver, 40 cartridges | 4 | 12 |
| Haversack, two days' rations | 5 | 15¼ |
| Canteen, filled | 4 | 4¼ |
| Pot, spoon, pan, knife | 1 | 4 |
| Blanket, roll | 4 | 11½ |
| Tobacco | | 3? |
| Intrenching tools, bag of miscellaneous implements | 13 | |
| Total | 34 | 2½ |

For Heavy Marching Order add 9 pounds 14¼ ounces.

Pickaxe, spade or shovel, crowbar, axe and saw should all be slung, if possible, over men's backs, also the bag of implements. Each armorer will carry an axe, weight 4 pounds, and a leather pouch or bag containing assembling and repairing tools and any spare parts for small arms—weight of bag 9 pounds.

*Stretchermen* will carry the following (Light Marching Order):

| | Pounds. | Ounces. |
|---|---|---|
| Haversack, two days' rations | 5 | 15¼ |
| Canteen, filled | 4 | 4¼ |
| Pot, spoon, pan, knife | 1 | 4 |
| Blanket, roll | 4 | 11½ |
| Tobacco | | 3? |
| Outfit, supplies, etc | 6 to 18 | |
| Total | 34 | 6½ |

For Heavy Marching Order add 9 pounds 4¼ ounces.

*Buglers* and *Signalmen:*

| | Pounds. | Ounces. |
|---|---|---|
| Waist-belt, 20 cartridges | 4 | 4¼ |
| Rifle | 8 | 12 |
| Haversack, two days' rations | 5 | 15¼ |
| Canteen, filled | 4 | 4¼ |
| Pot, spoon, pan, knife | 1 | 4 |
| Blanket, roll | 4 | 11½ |
| Tobacco | | 3? |
| *Signal kit | 5 | 7 |
| Total | 34 | 13¼ |

For Heavy Marching Order add 11 pounds 8½ ounces.

* *Buglers* would carry bugle instead of signal kit. Buglers and signalmen are not armed with a bayonet.

## Marines.

The arms and ammunition of the marines should be the same as furnished to the seamen—the latest improved magazine gun. The arm now furnished to the marine corps is a pattern of bygone days, also the cartridge box. Why this well-trained corps should be so armed and equipped ought to be a question for immediate consideration. The marines should wear brown leggings, and their helmets should be brown or dark gray in color, for service in the field; white belts should be discarded for active service. The arms for the marines should have dark leather slings attached, and each man should carry 80 rounds of ammunition, except when landed for short service, when 100 rounds per man should be carried and the Mills web belt used.

### Weight of Articles Carried.

*Light Marching Order.*

| | Pounds. | Ounces. |
|---|---|---|
| Rifle (Lee magazine, long barrel) | 9 | |
| Waist-belt, bayonet and scabbard | 3 | 12½ |
| 40 cartridges | 3 | 14 |
| Haversack and two days' rations | 5 | 15¾ |
| Canteen, filled | 4 | 4¼ |
| Pot, spoon, pan, knife | 1 | 4 |
| Knapsack, containing one undershirt, soap, towel, comb, one pair stockings, blanket (wool) | 8 | 10 |
| Tobacco | | 3? |
| Total | 36 | 15½ |

*Heavy Marching Order.*

| | Pounds. | Ounces. |
|---|---|---|
| Rifle (Lee magazine, long barrel) | 9 | |
| Waist-belt, bayonet and scabbard | 3 | 12½ |
| One belt over left shoulder | 1 | |
| 80 cartridges | 7 | 12 |
| Haversack and two days' rations | 5 | 15¾ |
| Canteen, filled | 4 | 4¼ |
| Pot, spoon, pan, knife | 1 | 4 |
| Knapsack | 2 | 2½ |
| Two blankets, wool and rubber, towel, soap, comb, one undershirt, one pair stockings, overcoat | 14 | 8¾ |
| Tobacco | | 3? |
| Total | 49 | 14¾ |

Here I want to emphasize the importance of frequently landing the brigade fully equipped. When the brigade is encamped for drill

and instruction, cooks will be sent from ships, and they will be under charge of the master-at-arms or the ship's corporal.

### Rations.

The quality of the U. S. Navy regulation ration as now served out on ships is excellent. It frequently happens that there is not time to cook food on shipboard when the landing party is called away, and once on shore it may not be possible to go into camp at meal times. Some form of food like the Bologna sausage should therefore be added to the ration, and put up in packages for landing parties. The Navy ration as now put up is in too large packages which are not easily handled. When articles are served out to a small number of men there is great waste.

Articles like pork, beef, beans, sugar, rice, etc., should be put up in ¼ and ½ barrels. Other articles of the ration should be put up in small boxes that one man could handle easily, marked "Landing Party," and kept ready for issue. The greatest care must be given to the drinking water, and when the water is bad, weak cold tea or coffee should be carried in the canteen. At these times an extra allowance of tea or coffee should be served out to the brigade, the former being preferable in hot climates.

## III.—Tactics.

The conditions of modern warfare having changed the movements of troops in actual battle, we must eliminate from the infantry tactics everything that is not suited to these modern conditions. There is a great cry at the present time for an immediate change in our tactics. It would appear that there are not so many changes demanded by the modern conditions of war, but that a confusion of terms has arisen in the application of the words *tactics* and *science*. Infantry tacticians seem to be of one accord that extended formations are necessary, and that night attacks will be more common, if we would provide against the destructive effects of an enemy's magazine rifles. Instead of masses marching in close formation, a loose order of fighting will have to be adopted, the aim being individual action, with all working to gain a common end. The axioms of the day are that "troo once engaged they cannot be relieved, and they must always to the front." I will not attempt to go into the much-vexed the hour, how to close with your enemy without being so

badly cut to pieces or so depleted by losses that any attempts to charge him would be idiotic; the greatest military writers of the day have failed to solve this question, and it is one that pertains more to the science of war. The first line of battle being formed by the skirmishers pushing forward, the supports would be gradually absorbed by this first line, when the main body of infantry and artillery would advance.

It is questionable if much is gained, except when advancing on a strongly entrenched position, by what has been so frequently advocated in the past few years, advancing by rushes. Running heats the blood and makes the nerves unsteady; firing under these conditions is a waste of ammunition and encourages the enemy. When advancing on the enemy, good marksmanship is sought after, and with running the conditions are unfavorable.

At Tel-el-Kebir the English Royal Marines advanced by rushes, and, as a result, were beaten into the enemy's works by another battalion that never stopped after once taking up the rapid advance, carrying everything with them.* It is impossible to lay down a positive rule; we must be governed by circumstances and the capabilities of the enemy.

The sailor possesses some of the highest of the qualities required by the tactics of the present day, and we should train him to develop these qualities to the utmost degree. Stiffness and regularity of movement are in direct contrast with his every-day life, and only that part of the manual of arms which would be required on the field of battle should be taught to him. Of what use is "Present arms," "Reverse arms," "Rest on arms," etc.? It is a waste of valuable time to teach these movements to the seaman. The "Position of the soldier" and "Setting up" drill, found in Upton's Tactics—and this would probably apply to any tactics—should not be imposed upon the seaman. It is simply absurd to talk to the sailor about "the little finger behind the seam of the trousers"; too great precision and uniformity of movement should not be required. When not marching, pieces should be invariably at an "order," and any order for a forward movement would be the signal to bring them to a "carry." All facings should be done with pieces at an "order," and thus avoid tiring the men with their constant weight. In moving to the attack, pieces should be brought to the position of "Arms port," a convenient position to take the "Ready" from, the piece and arms at the same

* Gen. Sir Edw. B. Hamley, in the *Nineteenth Century*.

time affording a considerable protection to the body. The position of the piece at "Arms port," in company or platoon front for clearing streets and forcing back a mob, is in common use; but it is a mistaken idea to use gentle measures when dealing with mobs. Nothing takes the nerve out of the proverbially cowardly mob so quick as the bayonet. The "Level trail" with the arms hanging naturally, so much used in England, is a very convenient way to carry the rifle while marching in column. Marching in line, the rear rank will open out one pace.

It is almost impossible for a sailor to learn so many bugle calls in the short time devoted to infantry drill; even the officers do not acquire them. "Advance," "Retreat," "Halt," "Fire," "Load," "Cease firing," "Assemble," "Charge," are all that are required; and they should be sounded frequently, that the men may be made accustomed to them. Ships' boats might be named "Advance," "Retreat," etc., and called away by bugle with these names. Should a boat be wanted while at general quarters, the boatswain's whistle would be used and the boat called away by name.

I am an advocate of the whistle for company officers. On the skirmish line it would be indispensable; and as the calls are very easily acquired and familiar to the sailor, the whistle or boatswain's call would serve the purpose better than the bugle. All pieces should have dark leather slings and the men should be accustomed to their use when firing.

In Upton's Tactics we should do away in the manual with "Present arms," "Secure arms," "Rest on arms," "Reverse arms," and "Support arms." "Carry arms" should take the place of "Present arms" in saluting. The heavy infantry "support" should be used, as it is adapted to the bolt-gun, which has no projecting hammer. At the order "Halt," when marching under arms, pieces should be brought to an "order arms" without further delay.

The strict drill of the soldier has for its object the disciplining of the men, that implicit obedience to orders may at all times be expected and obtained. The sailor having therefore been educated up to this implicit obedience on that most excellent parade-ground, the quarter-deck, why devote further time to his discipline at the risk of breaking his spirit of independence, which is now so much sought in the new school of fighting men demanded by the open fight-[illegible]mation. Better to teach men to be marksmen with no instruc-tion, than to have a dress-parade sailor with no idea how to

load and fire his piece, not to mention sighting at an object 500 yards away.

I have attempted to enumerate some of the changes in the manual of arms that would benefit the brigade under our present system of training. The adoption by the Navy of the U. S. Army Tactics, of whatever system it may be, will always be a necessary consequence; but the manual for the Navy must be suited to the arm, as well as to the sailor; the tactics for both Army and Navy being the same. Slight changes in the manual as at present given us in Upton's Tactics could be made with much good resulting therefrom; but these changes should be closely followed by every ship in the service, all adhering to the same drill. Marching in company front and the attempt to imitate the solid wall may receive the applause of the public; but to gain such results, what a sacrifice of valuable time that should have been devoted first to the loadings and firings, and second to the skirmish drill! Constant drilling of the company with small intervals between files, sighting and firing the piece, with the expenditure of plenty of small arm ammunition at target practice, is a necessity that must be apparent to all.

In deploying the modern fighting line, Upton's Tactics under the head of "To deploy the battalion as skirmishers by numbers," the battalion being in line, commends itself. To deploy from column, a certain number (specified) of companies would move to the right front into line, and a certain number (specified) to the left front into line. The deployment of infantry on the march from column should of course be carried out before the fire of the enemy's artillery has begun to tell on the ranks.

Under the present system of musketry instruction, the Navy has no field-firing to speak of, particularly when men are attached to sea-going ships. The time has come for an immediate change, not only that the naval brigade may be efficient, but that riflemen stationed in the tops and about ships' decks in battle may fire with accuracy. In this particular we could take pattern from the Army and have more rifle-range firing. Seamen are supplied with as good fire-arms as science can produce; but however excellent these arms may be, in the hands of unskilled marksmen no effective work can be performed. The men should be taught at the different Receiving Ships, both in rifle and machine gun firing.

If the time devoted to cleaning bright-work on shipboard were taken up in teaching the crew aiming drill and file-firing exercise, we

would have more efficient marksmen in the service, and necessarily more effective crews. Bright-work should be painted out, covered with canvas, or anything to get rid of it in a ship—its cost is not a subject for this paper.

Any unseemly haste to rush through the small-arm target practice in cruising ships is absolutely indefensible. And though we are much in want of a system of rifle range practice with small arms, still it lies in the power of a commander of a fleet to send his battalions ashore to compete for prizes and medals at the range when he assembles the vessels for their annual drills and inspections. At these contests, individual competition should be paramount and the marksmen be encouraged in their work.

In seagoing ships the officer of the deck in the afternoon watch should be relieved by a junior, when he would drill his company in the loadings and firings with the dummy cartridges. Cartridge boxes or belts should be filled and several rounds fired, to ascertain just what the men are capable of doing. On an examination of the pieces and the boxes or belts after each ten or fifteen rounds fired, and before the dummies are gathered from the deck by the quarter-gunner, the effectiveness of the firing drill would be known. This would not only accustom the men to be expert in the loadings and firings, but familiarize them with the breech mechanism of the piece. The rough usage to which the mechanism of all breech-loading firearms is subjected in service on shore calls for special attention to its care if the arms are to be kept in a serviceable condition. Arms and ammunition should be examined very frequently. Officers and men should be made familiar with all the parts of the magazine guns, and understand which parts are most likely to be rendered unserviceable. The men should be thoroughly taught the working of the breech mechanism, and when landed in the brigade, should frequently examine the gun and ammunition to see if the parts of the former are in good working order and that the ammunition is clean and fit for use. On fitting out an expedition, great pains should be taken to examine the ammunition, to see that it will fit the arms for which it is supplied. It cannot be too strongly impressed on the minds of drill officers that all drills not fitting the seaman for battle should be abolished, the manual should be the simplest possible and adapted to the requirements of the service.

When we realize it is claimed that the modern arm in the hands of fairly drilled men requires the discharge from it of nearly twice the

mean weight of a man in lead before it effects his death, we cannot be too careful in our firing instructions. In firing, if any control is to be obtained over a command, the order "five rounds" or "ten rounds rapid fire" should be used. Under the head of fire discipline, I quote from General Von Kraft of the German army, who is authority on this important subject: "I have often remarked how much fire discipline is weakened in action when the element of danger makes itself sensible. Troops imperfectly trained do not aim, they do not even fire, they only let off their pieces. . . . . . But how much more trouble is required before we can train the infantry soldier to pay attention to orders and signals during all the excitement of battle, to observe the object to be aimed at, the sight and mode of firing to be used, and to cease firing when the specified number of rounds has been expended. . . . . But if, as we have remarked, soldiers must already attain to a certain pitch of fire discipline before you can be sure of getting them even to bring their rifles to the shoulder in battle, how much greater pains must be taken before you can get them to take aim. . . . . When firing once begins men get easily out of hand unless restrained by an iron discipline. . . . . It is but human nature that a soldier should derive some comfort from the noise made by his own gun when it goes off. The more raw the soldier the more will he be inclined to 'shoot himself into courage.' . . . . Taking such facts into consideration, we cannot help doubting whether the order 'Five rounds rapid fire' when given at close quarters, say 300 yards, will be attended to."

*The Elementary Light Artillery Tactics* as now taught at the Naval School, Annapolis, and generally throughout the service, appear to be all that is desired. The men should not carry bayonets and cutlasses, and the drill should be completed for the gun with limber, and the crew increased to 23 men, if we would guard against the new dangers to which artillery is exposed by the development of rifle fire and the difficulties encountered in the supply of ammunition. In the *Elementary Tactics* we must confine ourselves to one system of drills—and there are many good systems—for all the service, eliminating everything not tending to efficiency on the field of battle. The modern conditions of war demand that for *Grand Tactics* the movements of guns in battle must be at a "double." This fact is supported by the field movements in action of European artillery, which require the guns to be moved by horses at a run. By doing away with cutlasses and bayonets, the former being liable to get between

the men's legs, not to speak of the extra weight and general uselessness of both, the guns' crews are as near flying-light as it is possible to make them, and at the same time they retain their efficiency, care being taken not to bring guns into action without infantry supports *in advance.*

Wishing to emphasize what has been said before, I would again call attention to the necessity of simple and effective drills in both the artillery and infantry, and the avoidance of *ceremonies* that belong to the parade-soldier. As little time as possible should be devoted to dress parades.

## THE DISEMBARKATION AND LANDING OF THE NAVAL BRIGADE.

In the disembarkation of the brigade great care and attention should be given to the boat organization. Each company of infantry (seamen) should land in the two ships' boats belonging to the division of which the company forms a part; being at all times accustomed to go in these boats, there will be no confusion. The larger boat will be in charge of the captain of the company—the lieutenant of the division—a junior officer of the division being in charge of the smaller boat. These two boats must always keep together, the larger one being on the right, and in forming the "order before landing," must take the same relative position in the line as the company holds in the brigade when formed on the beach.

The rifle howitzers and machine guns will go in the heavy boats. Three or four hammocks placed in the bows of boats, about the pedestal for the revolving cannon, would be a great protection to the crews of the guns in action. The marines will land in separate boats pulled by sailors, the latter being detailed from companies belonging to the reserve; though, with a system of boat drill in this corps, the marines could in a short time manage their own boats. A company of marines with their officers should be assigned to two boats, the boats keeping together.

The boat divisions in the "order before landing" will be commanded by the battalion commanders, each battalion forming one division of boats. The senior officer's boat of each division should have a mast, from which signals should be made and repeated; and should also carry signal books, spyglass, and a box containing medical supplies and outfit. Each boat must be provided with a signal book and answering pennant.

Each division of boats should have a distinguishing flag, and each boat should be numbered in the "order before landing" from right to left consecutively, 1, 2, 3, etc., commencing on the right of the skirmishing boats down the line, then to the right of the main body down that line, and the same way with the reserve and hospital boats. The artillery boats should be lettered from right to left, A, B, C, etc., to distinguish them from the other boats. Boats should have their numbers and letters painted on canvas, large size, and nailed to the stern and both bows; if possible, the numbers of the same color as the divisional flags. Each boat must carry an anchor and chain or rope, and in landing the boats must anchor by the stern, going ashore bows first.

It adds considerably to the comfort of a landing party if they can get on shore dry-shod, and to do this gang-boards could be carried slung over the gunwales of the boats underneath the oars; spare pieces of lumber found on shipboard and the carpenter's bench could be utilized for this purpose. Each boat should carry a bucket for bailing, materials for stopping shot holes, and a breaker of water. Intrenching tools, rope ladders, etc., should also be distributed among boats. Boats will carry their own ammunition. Spare ammunition and extra belts for the infantry will be carried in boxes—it might be more convenient to carry the latter in canvas bags. Empty powder tanks carried in boats make good magazines for the storage of ammunition when it is put up in canvas bags. The amount of ammunition will depend upon the nature of the service.

Before undertaking an expedition, proper means for the transportation of ammunition supplies, camp equipage, etc., should be provided by the quartermaster. Improvised means of transportation with carts made on shipboard should be the last resort, for they seldom answer the purpose required of them. Life rafts, or temporary rafts, are very convenient for landing, and a great assistance in getting ammunition and supplies on shore. No pains should be spared to land men and outfit dry.

If transportation is to be obtained and a lengthened stay on shore is to be made in encampment, boats should carry stoves, one for every two companies of infantry or four companies of artillery; also two scouse kettles and four mess kettles, sails and spars for tents, provisions and water.

It must be borne in mind that the nature of the service to be performed governs the preparations of the naval brigade. The more distant the service from the base of supplies, and the longer the

stay, the more the brigade must be governed in its movements by the rules laid down for a brigade of infantry; and those who would study this interesting subject are referred to that admirable work, "The Soldier's Pocket-Book," by Lieutenant General Sir G. J. Wolseley.

The light-draft vessels should anchor near beach to protect the landing, and also act as a base for supplies. They should keep as near to landing party during the time the force is on shore as the depth of water will permit, one vessel being used for the ordnance boat and another for provisions and hospital. Several of the vessels that are to cover landing should be provided with electric search lights. Should the landing be made in the night time it would be well to have three covering vessels with search lights, one on either flank and the other behind the centre of the "order before landing." These vessels would keep out of the effective range of shore batteries, or move about, altering their range and position frequently. They would light up the beach with their electric lights, and the landing force would approach the shore in the dark zones between the lights, so as not to be seen by the enemy. The brigade once landed, the search lights would be used to light up the country in the direction of the enemy, and good lookouts stationed aloft would report any suspicious movements, when signal would be made to the force on shore.

In forming the "order before landing" (see Plate I.) each boat should take the station assigned it in the organization; the presumption is that every officer has been made acquainted with all the details of the organization both before and after landing. When the distance to the shore is great, boats should be towed to a convenient place from the landing and out of range. The boats mounting the heavier guns of the artillery will be on the extreme flanks of the "order before landing," and next to them the light guns; all the artillery boats in echelon formation, with the main body of the infantry between. Two boats' length in advance of the centre of the main body of infantry, the skirmishers in light fast boats should be massed, with a few machine guns on the flanks, if desired.

The skirmishers, generally speaking, would be taken from the companies of marines. The reserve will be in the third line in rear of main body, and it would consist of about one-sixth of whole force; they are not to land until main body is well established on shore and has moved back from the beach. The hospital boats will be three boats' lengths in rear of centre of main body of infantry. These

boats will be pulled by the stretchermen, and they should be light single banked boats, containing medical officers and outfit, flying the hospital flag. Hospital boats will land with the main body of infantry, under charge of the medical officers and under orders of the chief of staff. The first line—skirmishers—should be two boats' lengths apart. The second line, main body, two boats' lengths in rear of skirmishers and one boat's length apart. The third line, reserve, three boats' lengths in rear of main body and one boat's length apart. The hospital boats in rear of centre of main body three boats' lengths, and in pairs one boat's length apart. If there should be opposition to the landing of the brigade, the beach would be cleared by the covering vessels and artillery, and in the event of a heavy fire being directed on the boats it may be necessary to open out the "order before landing" and land on a more extended front. Signal being made by the commander of the brigade, the skirmishers will pull in and land, deploying as soon as landed, taking advantage of such shelter as the ground may offer, after which, signal would be made for main body to land with light machine guns, followed by rest of artillery. The main body having advanced from the beach, the reserve would land.

If it be not the intention that the brigade should remain on shore, any length of time, the landing once effected, to the larger boats with artillery four boat-keepers will be allowed, and to the smaller ones two boat-keepers. The boat-keepers will have their boats out to their anchors after landing, turning the boats' bows out with stern lines to the beach, one man remaining in each boat to veer in when ordered. The boat-keepers are in excess of the number of men allowed to each company. All the artillery boats should be prepared to mount and fight their guns in the sterns of boats, though this might not be possible with the steam launches.

Each division of boats should be careful to keep together in their assigned places with the division flag displayed, one of the boats in each division displaying the flag from its mast. Always being prepared to embark under fire of an enemy, each division of boats will be under charge of an officer, with an officer selected to command on the beach, styled beach-master. The beach-master will have charge of all the boats and force left at the beach, and he will see that the boats are in readiness to embark all the brigade at a moment's notice. He will keep up communication by signal or otherwise with the covering vessels, and if possible with the main force. Such precautions as seizing any commanding position and throwing up breastworks

would be performed by the beach-master. To prevent surprise, he should throw out a picket, and when circumstances require it, a squad of petty officers should be added to his force.

The preparations for embarking having been carefully attended to, on the approach of the brigade the boats will drop in near the beach. If the brigade is pursued by the enemy, entrenchments thrown up by the beach party will be manned, and a few pieces of artillery will be left with the infantry to keep back the enemy. While the main portion of the brigade is embarking, the covering vessels and artillery will keep up a cross fire on the beach until all the force has embarked, the skirmishers being the last to leave the beach.

In the disembarkation, many points come under consideration which require much thought and experience; such as the amount of opposition to be met with from the enemy on landing, the nature of the country, length and character of beach, depth of water and state of the tide. A low, broad, convex beach affords the safest place for the brigade to land, if opposition is to be met with from the enemy. If possible to obtain a chart of the landing place, no disembarkation should be made without one. This chart should show depth of water, character of bottom, and time of high and low water. Each commanding officer of a division or battalion and the beach-master should have a copy of this chart, with the *state of the tide* marked on it for the *time* of landing. It should also show the "order before landing" of the boats and the position of the covering vessels.

*Marines.*—The tactics of the marine corps being the tactics adopted for the United States army, the marines would assemble with the seamen in the brigade, with no confusion to the latter. The manual of the corps should be the same as that taught to the seamen in all their drills and service with the naval brigade; uniformity in the brigade must be sought after and obtained, and the smaller factor must give way.

All the officers and men of the marine corps should be instructed in the handling of machine guns both afloat and ashore. At the present time the marines suffer for want of experience at the rifle range. They are not landed as often as they should be for instruction in target practice and open-order fighting. If capable of pulling their own boats, they would be independent in their transportation to and from ships.

*Marches.*—When no opposition has been made to the landing of the naval brigade, a reconnoissance must be made to ascertain the

whereabouts of the enemy, the nature of the reconnoissance depending on the kind of information desired.

If proper care has been taken in fitting out the expedition, charts of the country will have been supplied, with cities, towns, villages, direction of roads, streams, etc., and any high land marked on them, also a weather map and almanac to date. These charts would, if it were possible, have been prepared by the Bureau of Intelligence at Washington, otherwise by the commander of the expedition. Some idea of the country, its inhabitants, the wet and dry seasons, food, animals, etc., must first be obtained before an advance is made into the interior. The commander of the expedition will decide how the march is to be taken up, bearing in mind that a large force divided into two columns will march faster than in single column and with less fatigue to the men. It is also more easily deployed into line of battle; the maxim is, "separate for marching, unite for battle." In the formation of the order of march, guns and ammunition should be so placed in the column or columns that, upon falling in with the enemy, they would be in such position where most likely to be wanted. The time required to come up with the enemy would determine the formation of the order of march. Assuming that you are within striking distance of the enemy, and that a fight with him may take place at any time, care must be taken that each column has an advance guard and is in constant readiness for battle, and that the columns are strong enough to take care of themselves, and are within supporting distance. Artillery must never march alone, nor be left unsupported by infantry. Signalmen must accompany the advance guard. A flank patrol would also be necessary, and communication must be kept up between it and the main column. See Plate II., Figs. 1, 2.

At night, the advance guard, unexpectedly falling in with the enemy, must attack him immediately; there is nothing else left to do if the main column is to gain time for preparation. If necessary, the men and officers must sacrifice their lives, for upon the stand that the advance guard makes, the fate of the main column may depend. If forced back, under no circumstances must they retreat on the main column, but must retire on either side, unmasking its front.

*Marches in retreat.*—In retreat, the order of march is the reverse of that in advance, the rear guard being much stronger, and from one-fourth to one-third of the whole force, depending upon circumstances.

*Street fighting.*—In the occupation of towns and cities, street fighting will always play a prominent part in the work required of the naval brigade, and too much time and attention cannot be devoted to its study. A map of the place to be occupied, showing principal streets, squares and public buildings, should be obtained. Having determined upon a plan of operation, move in two or three columns toward the central portion of the place, and occupy a prominent square where the people are in the habit of congregating. Columns should keep up lateral communication with each other, and a body of pioneers should precede each, supplied with gun-cotton or other portable explosive for blowing down doors, buildings and barricades. A column meeting with barricades should not attempt to carry them in front if time will permit of their being turned by working to their rear through adjoining buildings. Advantage should be taken of any flat-roofed houses in working a column through a city. The advancing columns should be closely followed by the supports; surrounded by burning and falling buildings, with firing in every direction, men become bewildered and hesitating if they are not well supported.

In the advance, do not leave burning buildings in your rear if they threaten to cut off your line of retreat. Your forces once established, look to the water supply, and seize any fire engines. The engines should be overhauled and put in order by the force of firemen from the pioneers that accompany the expedition.

If you are fighting to obtain possession of a city, seize all food supplies; all the inhabitants that remain in the city should be enrolled and set to work, and everybody put on the same allowance of food. Arrest any one found on the streets between sunset and sunrise. Establish a signal station on highest building near to headquarters, or at headquarters if within signal distance of fleet. No officer or man should be allowed on the streets without arms or equipments. Keep open your line of retreat, but do not forget that a small force of determined men can keep at bay, in a well-barricaded building, many times their number; in fact, do not allow yourself to be burnt out and you can stay until relief comes, provided your food holds out. Remember the history of the Pittsburg labor riots of 1877 and the cooped up militia in the engine-house of the Pennsylvania Railroad.*

Should your object be to quell a riot or insurrection, establish your headquarters at the town or city hall; place yourself in communication

* "The United Service," Vol. I., Pittsburg Riots.

with the civil authorities; organize a police force, or lend all aid in your power to the regular force of the place. Barricade and be prepared to defend building or buildings in which your forces are located; two buildings commanding each other are better than one. Never, under any circumstances, permit more than two-thirds of your force to be absent from headquarters on patrol or other duty. If you take any prisoners, do not confine them in your headquarters. Never permit any strangers to inspect your preparations for defense. Arrest any one found looting; impress upon the minds of your officers and men that no property of any kind must be taken; everything that is found must be turned in to the quartermaster. There is nothing so demoralizing to a naval force as to allow men to appropriate articles; the very severest punishment must be inflicted for looting, if any discipline is to be maintained. Sentries should be placed over all buildings near to headquarters where liquors are stored; and above all things, never locate a command in any building without first making a careful inspection to ascertain if there are any spirituous liquors stored therein.

*Bivouac.*—Plate III. illustrates the general principles of bivouacing with outposts thrown out in the direction of the enemy; when necessary, the flanks and rear would also be protected. The general rule is that about one-sixth of the whole force should be employed on outpost work—the most important duty devolving upon the brigade.

As it takes a very considerable time to break out of tents and strike them, they would not be used in the presence of an enemy or when anticipating an attack.

The German system of outposts is probably the best and most simple. Some 400 paces to the front of the first line, double sentries are placed—this is the only distance given; the other distances, the reserve from the first line, also from main column, are at the option of the commanding officer of the outposts, he being governed by the "general state of affairs and the time the main body requires to get ready for action." In locating the outposts it would be well to remember that one officer should command on each front of the camp; by this means any confusion in the location of the outposts is avoided. The officer commanding the outpost should belong to the command to which the detail for outpost duty also belongs.

*Camping* (Encampment, Plate IV.).—In selecting a site for laying out a camp, when not in the presence of an enemy, we must

consider sanitary conditions, nature of the ground with regard to the comfort of the men, and the supply of wood and water. An abundance of fire-wood and plenty of fresh water near at hand make any locality a desirable one. The form of the camp will generally be suited to the ground, both artillery and infantry camping on ground best suited to them. In going into camp, each battalion of the brigade would encamp in column of divisions, the tents of each division facing each other, being arranged in two lines and trenched. As far as practicable a general alignment should be preserved, though regularity should not be sought after over more important considerations. The commanding officer of the brigade, also the battalion commanders, should have distinguishing flags on flagstaffs to indicate their headquarters.

In encampment the routine is established by the commander of the brigade, due regard being given to the season of the year.

*Camp routine*, when brigade is landed for drill and instruction:

h. m.
A. M.—4.00—Call cooks.
5.00—Call bugler of guard.
5.10—Assembly of buglers.
5.15—Bugles and drum march through camp.
5.25—Reveille, assembly, coffee.
6.30—Breakfast.
7.15—Sick call, fatigue call, police camp.
8.00—First sergeant's call, morning reports.
8.30—Drill call.
11.00—Recall from drill.
11.30—Assembly, guard mounting.
12.00—Dinner.
P. M.—1.00—Drill call.
2.00—Serve out provisions.
3.00—Recall from drill.
5.00—Battalions form.
5.15—Brigade forms for dress parade.
5.45—Supper, sundown retreat, orders, details for day following.
8.45—Assembly of buglers.
8.50—Bugles and drum march through camp.
9.00—Tattoo, assembly.
9.15—Bugles, lights out.

*To Arms* is the signal of alarm, when the brigade will turn out under arms. The *general* is the signal to break camp, preparatory to marching.

*Base.*—The base of operations of the naval brigade is an important consideration that presents itself to us. Under most circumstances the fleet would be the base, but in operating on rivers and streams, some of the fighting vessels of the fleet with a despatch boat should accompany the boats to be used as a base, if the depth of water will allow. Should the water be shallow, steam launches, armed with Hotchkiss revolving cannon and the single barrel Hotchkiss, with temporary protection for their crews, should accompany the landing force. These launches would not land, and should have large crews, every man in the boat being armed with the magazine rifle, which should be kept at hand ready for use when occasion demanded. Vessels and steam launches accompanying the brigade should, if possible, keep up communication with the force and be prepared to furnish anything necessity required. Accompanying vessels should have large supplies of provisions, ammunition and medical outfit.

*In conclusion,* the essayist has endeavored to avoid the common fault of the day, when treating of a professional subject, of dealing in generalities. In making suggestions he has attempted to name something better, and solve, with useful details, where he has condemned. To condemn the practices of the service without working out and presenting in detailed form something more worthy of trial, is to remain at a standstill and fail of the purpose sought.

There is nothing in this essay that the writer claims as new and untried; were he to do so, it might detract from its value. Having consulted every work within his reach published on the subject of Naval Brigades, and they are not many, he has summarized and placed the information obtained, with his own experience added, in such shape that he hopes it may supply a long and growing want, benefit the service at large, and be of *practical use* to the brigade commander. Taking hold of a practical subject, the essayist has attempted a practical solution, avoiding any digressions to new-hatched thoughts which would add length to the essay with no beneficial results. Being a great believer in the naval brigade and its valuable work, he would at the same time jealously guard the seaman from the machinations of the infantry-crank and toy-soldier, always keeping in mind the *materia circa quam* of a navy.

# INDEX.

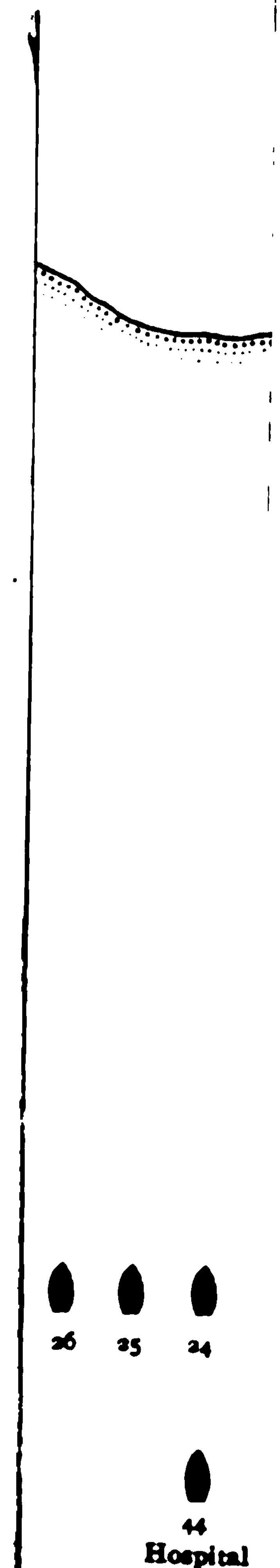



PLATE I.

part.
l boats, one bo
dy, two boats'

proportions, if the required power is to be obtained. A trained dockyard force will get this power, but with our present force of untrained stokers that power will never again be approached. We certainly need a trained dockyard force for power trials; but we need, and pressingly need, a system of training for all the enlisted men of the engineer's force. Much of the plan that I shall propose is not new.

Without going into details, the central idea of my scheme is that all enlisted men of the engineer's force shall have as thorough a training as may be possible in stoking all kinds of coal used in the furnaces of marine boilers, under the conditions of forced and of natural draught, and shall be taught to do the ordinary work of the engine and fire room, under competent supervision; this instruction to be given before the man is sent to a cruising ship. We should thus have in time a body of trained workmen, men who would work intelligently, whether stoking or overhauling machinery, and the engineer officer in charge would be relieved from the necessity of pointing out the exact spot in a furnace where each shovelful of coal should go, or of consuming valuable time to show an inexperienced man how to hold a wrench.

To begin, the apprentice system should apply to the engineer's force. A certain proportion of the boys enlisted on the Minnesota should be kept there to receive instruction by engineer officers detailed for that purpose. The boys should be taught how to handle tools, how to pack stuffing-boxes, to do rough blacksmithing, and to take down and to put together parts of machinery. They should be made familiar with machinery; and, above all, they should be taught the almost lost art, in our Navy, of the stoker. When we get steam training ships, as now seems probable we shall do, the instruction of the engineer apprentices should be continued by their instructors. Practical instruction in stoking with forced draught would be possible. In time we should be able to get all our trained workmen for the two great branches of the service from the same source—the training squadron.

As an extension of this system of training, such of the boys as show marked ability should be sent to the machine shop of some navy yard and required to serve a regular apprenticeship. From this class the machinists of the Navy should be recruited. While serving their apprenticeship in the machine shop, these boys would still be under the instruction of an engineer officer. They could live on the receiving ship at that yard. On the training ships a system of

instruction should be established having rewards for the least coal used to obtain required results, or rewards for taking down and putting up machinery in the least time and in the best manner.

For our present most pressing needs, every receiving ship should be a training school. These schools are ready for the pupils, for on nearly all of them there is machinery, antiquated no doubt, but yet affording a field for instruction in handling the ordinary tools used on shipboard, and for practical lessons in stoking. There should be two engineer officers on every receiving ship designated as a recruiting station for firemen. There should be two receiving ships so designated, one at Norfolk and the other at Boston. The engineer officers detailed as recruiting officers and as instructors should be responsible for the proper training of the men enlisted by them. All men presenting themselves for enlistment as firemen should, after the examination now required, and after enlistment, be given instruction in stoking and in handling the ordinary tools found on board ship. With our present short term of enlistment, three months is probably all the time that can be allowed for this training. The men should be divided into classes, all those enlisting in a month forming a class. The great object to be aimed at in this three months' course is to make the men put coal in a furnace intelligently, and to make them handy in the use of tools required in the ordinary repair-work of the engine and fire room.

There should be but one class of firemen in the Navy, with a uniform rate of pay, that of the present first-class firemen. The firemen should not be recruited from the coal-heavers, unless it is impossible to get qualified men from the training squadron or from the receiving ships. At the end of a cruise, such coal-heavers as have shown fitness and aptitude should have their discharges so worded that they could readily enlist as firemen at the proper recruiting station, and then get the benefit of the three months' training.

## DISCUSSION.

THE CHAIRMAN.—*Gentlemen*:—We meet this afternoon to discuss the subject of P. A. Engineer Parks' paper on training enlisted men for the engineer force of the Navy. It is a very important subject, and one that is growing more and more important as the Navy is being increased with modern men-of-war. Machinery is used to such an extent on the lately constructed naval vessels that to the efficient working of ship and battery some mechanical knowledge is as essential for the seamen as for the firemen.

How this knowledge is to be imparted, what inducements are to be offered to the apprentice or enlisted man to become a skilled mechanic, or even an efficient fireman or stoker, are matters involving an acquaintance with the enlisted man's surroundings, inclinations and aspirations.

To exchange our views on this important subject is carrying out one of the objects which the Naval Institute is designed to encourage. Those who have thought much upon the subject, and those who have not, will no doubt receive, from a discussion of the paper before us, ideas that may lead to a definite and efficient plan.

With this aim in view, I trust each one will indulge in a free and liberal expression of his views.

Lieutenant E. K. MOORE.—*Mr. Chairman and Gentlemen*:—The subject before the meeting is certainly a very important one, and I think we all realize the necessity of trained firemen and machinists for our new ships. The present state of our merchant marine is such that I doubt very much if we could get the number we would require from that source.

The subject is one about which I have not thought enough to wish to put myself on record. However, I take issue with the author on one point, and that is, the selecting of a certain number of the apprentices who enlist on the Minnesota and retaining them for apprenticeship in the fire room. In lieu of that I would suggest that the boys be sent on board the training ships, and when qualified for transfer from those training ships, that they be sent to some school, on shore or afloat, for their apprenticeship as firemen, machinists, or whatever other billet they may choose in the engineer force. In the first place, the boy, or any one else who goes to sea, must have a naval training before he can be capable of doing anything useful on board ship. If the boy was trained and taught the different parts of the ship, how to row, how to swim, how to take proper care of himself, of his clothes, bag and hammock, and, besides this, a certain amount of seamanship, ordnance and soldiering, he would then require no more instruction on board ship except in the one professional branch which he might select or be selected for in the future. If he could then be sent to a steamship to serve his apprenticeship, I think it would be better than to take him as a green boy from the street or farm or whatever other place he may come from, and place him at once in the fire room.

Again, I do not think it a good idea to teach apprentices for the fire room on the steam apprentice ships. In the first place, if we have steam on the

apprentice ship it will only be auxiliary, and the machinery will be entirely different from that on any other ship in which he might afterwards serve. The training he would get on the auxiliary steamship would, for instance, be of little use on the Boston, Atlanta, or other new ship. In addition to this, we already have too much to teach the apprentice in the short time that he is allowed to remain on the training ship.

The Minnesota, Franklin, and Wabash are ships of the old type, but might be used for the first part of the training of firemen-apprentices. Then when far enough advanced they could be sent to cruising vessels having boilers and engines of more modern type, there to complete their education and serve out their terms of enlistment. From those that have served their apprenticeship as firemen might be selected a certain number to be re-enlisted as apprentice machinists and distributed amongst the different Navy Yards, to work in the machine shops and on the engines and boilers of vessels fitting for sea. In this way they would get a knowledge not only of the handling of tools, but also of the engines they might be called upon to run in future. Being enlisted, they would not be liable to be laid off on account of want of funds, but would be an addition to the regular force.

Lieutenant J. B. MURDOCK.—*Mr. Chairman and Gentlemen*:—I have not given the subject much consideration, but there are one or two points suggested to me by the paper and by what has just been said. I fully approve of the training proposed, but differ with the author as to the method of carrying it out.

The great need of the service to-day is a higher technical training to fit the men for their duties on board our new vessels. A new class of men is called for on deck as well as in the engine room, and the service would be greatly benefited if the training squadron could supply the latter as well as the former. Owing to the comparatively small number of men allowed the new vessels, the men of the engineer's force will probably have to take part in landing parties, and are, indeed, even now required to be instructed in small arms and machine gun drill. It will be a great advantage if they are given a systematic training, and are subjected to the habits of discipline in which apprentices are educated in the training ships.

I am decidedly opposed to the idea of educating the engineer apprentices on the Minnesota in New York harbor. If the steam training ships which the Chief of the Bureau of Equipment and Recruiting has been requesting are ever built, the natural place to educate boys for fire-room work will be on board those vessels at sea. In that case, let each boy take his turn at stoking, as well as at instruction in seamanship and ordnance, and if any develop peculiar fitness for the work, let greater facilities be afforded them.

I do not think, however, that every boy developing mechanical skill or ingenuity should be assigned to the engineer's force. Machinery is being introduced into every part of our new ships, and a knowledge of tools is very necessary on deck also.

I wish to call attention to the fact that at present the pay of first-class fire-

man, the only class provided for in the paper, is the same as that of chief boatswain's mate, and this will naturally attract men to the engineer's force, leaving an inferior class on deck to perform duties requiring at least equal skill and knowledge. Our modern training must fit men for the greatly changed conditions of our new vessels; and, if necessary, somewhat of the present training should be left out, as we cannot expect to make our apprentices "Jacks of all trades."

Ensign DENFELD.—*Mr. Chairman and Gentlemen*:—The work in the fire room is too hard and too confining for those who have not reached their full growth. By training boys in the fire room there will grow up an inferior class of men who cannot be depended upon in emergencies. A few years ago the system of training boys in the Navy for the engineer's force was given up after a short trial. There was a marked difference in physical appearance between the fire-room boys and those on deck.

It is very essential that a course of training should be given to the men who enter the engineer's force—for a period of one year, let us say. During this time enough military and technical training can be given to fit men for the routine work on board a man-of-war. At most of the shore stations the necessary course of training can be given, and it will take only a short time on shipboard for those who have completed it to become masters of the situation.

Commander HIGGINSON.—*Mr. Chairman and Gentlemen*:—I cannot help approving of this idea of educating naval apprentices, because it seems to me we stand much in need of some such system. I think that every boy destined for the Navy should receive at the commencement of his career a military and nautical education, whatever position he may subsequently be called upon to fill, and whether before or abaft the mast. It is only by following this general principle that the efficiency, mobility, and harmony of the service can be maintained. The Naval Academy is doing some good work in this direction, and might with profit extend its sphere of action; and now, in filling the engineer force with trained men, let the training squadron do for the rank and file of the service what the Academy is doing for the officers.

As has been remarked by Mr. Denfeld, the boy destined for the engineer force should be of some growth and maturity, and his earlier years cannot be better employed than on board the training squadron. He will not only acquire there the necessary physique, but he will gain that nautical basis to his education which will enable him always to feel at home upon the sea. Many officers have noted how little general interest in the service is oftentimes found in the engineer force, and this unsympathetic attitude towards their surroundings and associates has presented at times a serious impediment to the complete harmony and discipline of the ship. Now it seems to me that this uncongenial feeling may be eliminated by taking boys from the training squadron and training them for the engineer force. Then not only the officers but the rank and file would be possessed of a sailor's knowledge, and be available for use in case of an emergency.

I think there should be no difficulty as to the details of this scheme, and they should be worked out in harmony with the present system of naval training, and under the same direction. It is only a part of a general system of naval education for boys and should be under one head. The boys may be educated for stokers, firemen, or machinists, according to their capacities or inclinations, and either afloat or ashore as may be found most advantageous. Inasmuch, however, as after his double education he becomes of double value to the Government, his pay, if not double, should be in excess of that of the man who is only educated in one direction. This would be only fair treatment of skilled labor, and would offer an incentive to the boys to undertake the additional training. All boys entering the engineer force should be required to serve for a length of time—not less than ten years—sufficient to reimburse the Government for the education bestowed upon them. It must be remembered that, unlike the sailor, the engineer can find a market for his wares on shore, and it is against such a misuse of benefits conferred that the precautions should be taken.

Lieutenant ROHRER.—*Mr. Chairman and Gentlemen*:—It is admitted by all that a skillful and well-qualified engineer's force is necessary on board our ships. The use of steam and machinery is constantly increasing, and the better trained our firemen and artificers are the more power will they develop from a given amount of coal, and with the least wear and tear of machinery. It would be very satisfactory if we could secure a sufficient number from among the boys who have gone through the course of the present training system, and who have arrived at the requisite physical maturity for further training to qualify them as firemen and artificers. What they have already acquired would of course make them so much more valuable in the new field to which they would be transferred. It is a question in my mind, however, whether the fire and engine rooms offer sufficient attraction and inducement to youths who have qualified as seamen to warrant a hope that the engineer's force could be sufficiently recruited in this way. If it can be done, it were well to do it so.

Supposing it cannot be so recruited, I would suggest a system of apprenticeship to be carried out at all our naval stations where boilers and machinery are in constant use. The youths should be from eighteen to twenty-two years of age, of the necessary strength and robustness to stand the work of our more trying fire rooms. They should be shipped as general engineering force apprentices for five years. They should be thoroughly instructed in firing, in caring for boilers, and in handling and using such tools as they may develop a capacity to use. The brighter and more ambitious should receive special training to qualify them as ship's machinists, coppersmiths, blacksmiths, oilers, water-tenders, and the like. Upon passing prescribed examinations for the various positions which the ambition of each apprentice warrants him to try for, they should be put into the general service with the assurance that they are to have the rates for which they have qualified, when vacancies exist.

It appears to me that a valuable set of men could thus be obtained, though they would not have been set up as soldiers. To attain this end, they could

be quartered upon the receiving ships or barracks at the various stations, and there receive at specified times the military instruction, which certainly is very desirable and important. Or, these apprentices, after a certain time of training on shore at the naval stations, might be transferred to a steam cruiser especially set apart for the purpose, there to finish their training, and then to be transferred to the regular cruising ships. As to the military training of the engineer's force of our ships, I see no reason why the men composing it should not be set up as soldiers while they are waiting on the receiving ships for transfer to the cruisers.

It seems to me that some system like this will provide the force we want; and it can then be recruited from the existing training system, from the merchant marine, and from the farm and street. Take the competent youths from wheresoever they may come, train them at the naval stations upon an elaborated and sensible plan, turn them into the special cruiser and then into the general service, securing to them the higher ratings for which they prove themselves qualified,—this, in brief, is the plan that I would suggest. What I have said will, I hope, be understood simply as a suggestion which may possibly be of use in solving the problem under discussion.

THE CHAIRMAN.—*Gentlemen*:—As I said in my previous remarks, we must consider the enlisted man's surroundings, his inclinations, and his aspirations. To improve the first, we must make them such that he will not only be enabled to live with all possible comfort on board ship, but also in such a manner as to encourage his self-respect and generate a liking for his life. A very great improvement is being accomplished in this respect in his treatment and accommodations. The nearer we approach a satisfactory state in these matters, the greater will be his inclination to remain where he is guaranteed a sure and permanent remuneration for his services and a just and considerate supervision. The exact course to be pursued to attain these results, although germane to the subject of the paper, I will not now undertake to discuss, nor give my views, except to say that the enlisted man, like every other, must have his aspirations for higher place and position considered and whetted, to obtain from him valuable and beneficial results.

The question of obtaining competent machinists and firemen for the service has not, I must say, engrossed so much of my attention as that of obtaining competent naval seamen, for the reason that I have felt that the duties of these men in the service are so similar to those on all modern steamships that a supply could always be obtained, particularly as the pay in the service is tolerably fair, and, except in occasional instances, the work is not arduous.

The question that has given me most concern is what inducements can be offered to a man to become an efficient stoker or fireman. If a plan can be devised by which men can be trained and retained in the service to fill these positions it would certainly be desirable in every respect. Would a young man on board of a man-of-war have the means of making himself a skilled mechanic, so that he could hope to receive the rate of machinist? I think not. This knowledge he must obtain in a machine shop, either ashore or

afloat; and even after he has this knowledge, it is a question whether he will be willing to take a step down and make a cruise as a fireman. The introductory steps to becoming a stoker cannot be taken by a boy. The work requires a full-grown and tolerably strong man, unlike in this respect to the training to be a machinist or seaman, which not only can begin in youth, but it is advisable that it should so begin.

To obtain a supply of firemen and coal-heavers I would propose the following modification of Mr. Parks' plan. On the receiving ships at navy yards enlist men, not under 21 nor over 28 years of age, as firemen and coal-heavers. The qualifications for the former should be a fair knowledge of the duties of the rating, such as is obtained on the ordinary merchant steamer or tug, a common school education, and excellent physical powers. For the coal-heaver, the necessary physical power and a fair character. Have an engineer officer, with the requisite number of machinists, to instruct these men in their duties, affording them all the facilities necessary to this end. There is no doubt but that soon all the receiving ships will be lighted by electricity, and thus an opportunity will be afforded for instructing the firemen in the care of the dynamo and engine.

It would be, in my opinion, an excellent plan to have all the rebuilt monitors of the Miantonomoh class commissioned and stationed in our principal harbors, —one at least at this place,—and to have the firemen, before being drafted, made to go through a short course of instruction on board of them. These vessels could also be used to instruct such apprentices as, having served eighteen months in the training squadron, and shown a fair mechanical ability, may desire to enter the engineer force as machinists. Should naval seamen apprentices, after receiving their discharges on arriving at the age of twenty-one years, desire to enter the engineer force as firemen, they should be given the opportunity to do so, by re-enlisting them under their C. S. C., and instructing them in their duties on the monitors. The great advantage of having men in the engineer force who have received the training of the naval apprentice squadron would add so much to the military character and consequent efficiency of the ship or service that the attending time and expense would be amply returned to the Government.

The plan of educating machinists for the Navy at a navy yard I do not approve. Judging from an experience of three years in one of them, the work [illegible] and uncertain that the apprentices, if retained on the chronic giving [illegible] funds before the end of the fiscal year, are necessarily employed in [illegible] the shops and machinery in order, and not directly in learning their [illegible] the Navy will always have to depend in a great measure for its supply [illegible] and firemen on the merchant service. If we can leaven the num- [illegible] instructed as mentioned, I think we shall be accomplishing about [illegible] or hope for now. England, whose naval training system is [illegible] most complete in the world, does not, as far as I can ascertain, [illegible] specially for machinists and firemen. They are doubtless [illegible] dockyards and other sources. Commander Chadwick does [illegible] in his admirable book on the "Training of Seamen in England

and France." I do not mention this fact as the reason why we should not train our own engineer force, but simply cite the example as showing that the largest navy in the world has not yet been driven to this method of obtaining them. After we have created an adequate supply of trained naval seamen, which is the imperative present need of the service, we shall be better able to strive to create one of machinists and firemen. But until we do furnish a sufficient supply of men for those duties on our men-of-war that cannot be learned elsewhere, further steps than those mentioned I do not think absolutely necessary. We should simply be producing incomplete and unsatisfactory results.

I understand that allowing apprentices to go into the engineer force was tried at one time with good results. An old machinist in the service, now at this station, states that so many wanted to enter the engineer force that the plan had to be given up. That nearly all wanted to go might have been the case, as the pay of firemen is equal to that of the highest seamen petty officers in the Navy—in my opinion a very sad condition of affairs, and one not calculated to obtain and retain the most desirable material for seamen. The pay of the seamen petty officers of the first class should be raised to that of those with whom they rank.

As I have stated in my opening remarks, I have not given this matter the thought I ought, but what I have stated is my opinion at present. Further consideration of the remarks made here, and further reflection, may lead to modifications in my views.

Before adjourning we should thank P. A. Engineer Parks for the interest he has shown and his advocacy of a plan for the improvement of the personnel of the service. It is a healthy indication and one deserving our heartiest co-operation.

The following discussions were received in manuscript from some of those that were unable to be present at the reading of Mr. Parks' paper, but to whom proofs of the paper had been sent with a request for an expression of their views on the subject.

Commodore SCHLEY.—*Mr. Chairman and Gentlemen:*—The paper of P. A. Engineer Parks touching the training of men for the engineer force is in such complete accord with my own views on this subject that I endorse most he has said in his admirable presentation of this great need.

The argument he makes for higher training is supported by the fact that the contrivances employed to obtain high power in our new ships differ so widely from those in common use in our old ships that special training is essential to the men who are to be required to develop this increased power. When it is considered that the new engines are somewhat more complicated in design, quicker in motion, and that boilers differ in form and construction, that higher pressures are to be maintained, that there is a labyrinth of pipes and connections for pumping, that a new system of forced draught is to be employed, that

greater horse power per square foot of grate surface must be obtained, that the conditions of air-tight fire rooms change old requirements, it would seem almost ridiculous to expect untrained men to be of the slightest use in our new vessels like the Baltimore, Charleston, or Newark. As I understand the problem, we have a certain aggregate number of square feet of grate surface upon which to convert coal into energy. In the old ships with natural draught the possible horse power was from four to six. In the new vessels with forced draught there have been developed from eight to sixteen horses, with possibilities up to twenty horses. In other words, with the best picked coal we are to require at least 68 per cent more energy in the same area than ever before to obtain the power that is to accomplish the high speed of the new ships.

It goes almost without saying, that if these results are to be attained our men must be trained. I can conceive no other way to bring this result about; indeed, I think that the only reason for the failure to develop the required horse power of the Dolphin and the Atlanta is that the engineer force of these vessels is untrained to the new system. It is safe to say that each trip of these vessels will indicate improved results growing out of better acquaintance and more training with the new machines. This brings me to the suggestion that unless we train our men before placing them on board of the new ships, we shall be obliged to train them after going on board. This means simply that the new ship, under the latter circumstance, will be for several months unfit for duty, during which time she would be easily whipped by vessels of inferior power manned with a trained force.

I am free to say that I am committed entirely and earnestly to this matter of higher training of men who are to serve us in our new ships, and have intended to commence it as soon as we shall have succeeded in securing the steam training ships advocated since my accession to the Bureau.

With reference to the age at which this training should commence, I must differ with Mr. Parks, for the reason that the work to be done by the person trained requires the fuller physical and mental development of a man. The tendency of fire-room work to develop diseases of the heart in the adult would be a strong reason against training an undeveloped boy to this duty. Again, it would appear that the work to be done demands more strength of body and general intelligence than could be expected from a growing lad who learns rather by imitation than by the immediate exercise of his reasoning powers. No: I would train men of twenty-one years and over with more certainty of success and with less probability of injury to their health.

I have merely thrown these views together in the hope that the discu to follow may give more light upon this subject, or to invite sugge others who may have thought upon it.

Chief Engineer GEO. W. MELVILLE.—*Mr. Chai* n Although agreeing in the main with my brother officer th ing for their special duties on board ship, as in fact i compare the engineer department of a moder well-organized machine shop. In the macl down to the apprentice boy, all things work

of the work to do, and each man is responsible for the work done. Every mechanic employed is supposed to be able to do his day's work and do it well, misfits or mistakes causing the man's discharge, the apprentices alone being allowed a little latitude, because of the fact that they are the learners. I learned my trade in a machine shop, and if any man engaged as a machinist could not do his work he was discharged, and here ended the matter.

Not so, however, is this the case in a military organization. If a man manages to be shipped in a certain grade, he cannot be disrated without the form of a court-martial. He is not a responsible person with the danger of discharge from lucrative employment before him. In the machine shop—in fact in all manufacturing establishments—everything is done by rule and line. In a man-of-war fire room this cannot be: the fire and engine rooms are a scene of continually changing conditions and expedient. In the modern man-of-war or iron fighting machine—where we have anywhere from 400 to 800 tons of engine and boiler, and the most of it under tension, almost to the breaking point, either from pressure in the boilers or strain on the moving parts of the engine—the conditions are entirely different from that of the machine shop, and both officer and man must be alert to avoid accident, to substitute one part for another, make quick repair in emergencies, or make one system of pipes or valves do service entirely different from what they were intended for. In certain cases the engines must not be permitted to stop, or the battle is lost or won. Not so in the machine shop: when the bell rings, noon or night, all hands quit and go home. To-morrow morning will suffice to continue the construction of the fabric in hand, and if we are hurried we can put on more hands, and discharge them when the hurry is over.

To my mind, the great difficulty with the engineer force is the fact that there are so very few mechanics among them. A man cannot learn the trade of machinist or smith on board a ship of any kind; and because a man becomes familiar with tools or the use of tools in a crude way, he is rated by the officer put over him to the grade of the artisan class, thus spoiling a good, first-class fireman to make a worthless machinist or boilermaker, so-called. And were either out of employment, the last place they would dare to go and ask for employment at either trade would be in a machine or boiler shop. We might as well expect an excellent coachman to be a coachbuilder in any of its multifarious branches.

There are men shipped or rated in our service to-day in the mechanical branches who are totally ignorant of the trades they are supposed to follow, and who cannot do either engine, boiler, or smith work. I mean men who have not learned the trades, and cannot go into a shop on shore and do a job of work.

Mr. Parks may argue, "So much more the reason why we should drill or teach the men their duties." Firing or handling the machinery may be taught on board the ship, but the trades cannot be. And it is to this class of petty officers the engineer officer must look for intelligent aid in handling and repairing and keeping in repair the vast amount of machinery which is daily growing greater and more intricate. The day has gone by when any man who could shovel coal and pack a stuffing-box on a slow-moving, low-pressure

engine of 15 or 20 pounds of steam can be trusted with the high pressures now in vogue, and which are daily increasing. We must have the young, bright, intelligent engineer, who knows his responsibility and danger and can appreciate them, to direct the duller material that does his manual labor and keeps his machinery in repair.

He is required to give confidence to his subordinates by his coolness and intelligent supervision of the moving mass of machinery—not from deck or from his state-room through a speaking-tube: he must be right there among his men, through soot and black, heat and steam. Though he be called ignoble because he soils his hands, if he would be the efficient engineer and serve his Government as he should, he must do all this and more too, and let the pleasure be his that he, too, is a part of the modern fighting machine and the soul that gives it thought and movement. It seems impracticable to me to put men through a course of training for special service on speed trials—except on board of our cruising ships, where they soon get all the training in firing and overhauling the machinery it is possible for them to have—as my experience in the service has been that the men who did the running at sea employed all their time in port overhauling machinery, one ship alone excepted, the Lancaster, which at that time was an auxiliary-powered ship. Selections might be made from the well-known men who are shipped for general service that could be employed for this special duty for steam trials; but where these services are so seldom called for, I doubt if it would be good policy or convenient to hold such a body of men for that service. What would it avail us if we found, by a special force, on experimental trials, that a ship made 16 knots per hour on a coal consumption of 1.6 pounds per H.-P. per hour, if in practice, while cruising, we made but 14 knots and it cost 2.5 pounds of coal per H.-P.? I fear this is a rock on which many persons are splitting. A measured-mile speed trial cooked up and jockeyed for a record is very different from the actual cruising practice, and it is only on these special speed trials when the high speed of ship and economy of engine are shown. When the ship goes out into service, the actual fact of practical running is brought into play; and it is in our service as in all other services, whether naval or merchant marine.

The jockeying for high speed and economy lapses. Steam jackets and special appliances are shut off because they require more care and attention than can be shown them, because of the reduced force on board to attend to them, and the blooded horse with the fire of "Maud S." and her special jockey falls into the traces of the steady-going roadster or dray horse.

Having been attached to the Atlanta, I suppose I should be expected to say something concerning that magnificent ship, so much better than any we have ever had before in our service. We should be proud of her, though some of my fellows differ with me. She has plenty of engine and boiler, and should make 4000 horse power. The cause of her ill-success up to this time has not been alone a want of a trained force so much as a combination of conditions in a new [illegible]ruction, including forced draught, ventilation, arrangement of coal bunker passages, and the facilities of working under these new [illegible] There are other defects which will be remedied in new construc-

tions, and that will be palliated when she is formally accepted by the Government. Suffice it to say that the Government never before got so much ship for so little money, and the labor this ship has passed through will bring forth good fruit in the new constructions now in hand.

Mr. Parks will naturally ask what I propose instead of his scheme. I too would train men to do their work properly and well; but I would use the force as now enlisted. I would enlist no man in the artisan class unless he was a mechanic who had learned his trade in a properly equipped shop for the fabrication of machinery. I would not promote a man from the fireman class to the artisan class because there was a vacancy, and because he was a good oiler or water tender. I would promote coal-heavers to all grades below that of artisan, for all my experience has shown me that the coal-heaver at the end of a cruise makes the best fireman. He has been trained and drilled, and is still young and vigorous enough to do the duty of a fireman, and he won't last long. He will soon be burnt out, like an old grate bar, and will soon have to drop out to make way for the new material to be recruited from the able-bodied and most intelligent of the coal-heavers.

I would try to make the men happy so far as lay in the power of the commanding officer of the ship, and make them feel that, although black and grimy from heat, soot, and labor, they were part and parcel of the fighting machine; that their labor was honorable if well done, and that they shared in the honors of a well-drilled fighting machine; that they were not damned because they were grimy; and I would never degrade them by clearing the "brig" of its prisoners and roughs and rogues to recruit the fire-room force in an emergency. By recognizing these men and the labor they perform as necessary and essential to the success of the ship, they too would be made to feel that spirit of friendly rivalry that pervades the other parts of the ship, and it would take the weight off their minds that they are the "damned firemen."

Passed-Assistant Engineer A. M. MATTICE.—*Mr. Chairman and Gentlemen:*— I agree most heartily with the author that something must be done in the way of training men for the engineer's force of our prospective ships, but I differ from him in some respects as to what this something should be. In the first place, as great physical endurance is one of the first requisites of a good fireman, I should object to the enlistment of immature apprentice boys, and would offer inducements for men to enter the service who have had some previous experience in hard firing—on locomotives, for instance. They might be enlisted for a short period of probation, say six months, and if at the end of that time they proved acceptable, they could be enlisted for four years. I would have one or two small steamers in constant use, with forced draught, where these men, during their period of probation, could be trained in the working of modern marine boilers. The tugs of the Fortune class might be utilized for this purpose by replacing their present boilers by smaller ones fitted for forced draught. The men should spend the first six months of their long enlistment on board a steam receiving-ship and at a navy yard where they would be instructed in the use of tools.

But to get such men—and we will not be able to get along without them—

inducements must be offered. In the first place, we must give more pay. I know that this will be objected to immediately, as firemen now get more pay than other enlisted men of the same class. But labor is a merchantable article, and will bring what it is worth, and the more we pay, other things being equal, the better article will we get. Moreover, increased pay is not the only inducement which must be offered in order to obtain better firemen, as well as better men of other classes. The condition of the life of enlisted men on board ship must be improved; the fact must be recognized that they are human beings and should be treated as such. Their mode of messing must be made more decent; they should be allowed more leave of absence on shore after their day's work is done, instead of the infrequent "liberty" (most appropriately named) now granted; they should be paid their hard-earned money once a month, instead of having grudgingly doled out to them various pittances under the names of "monthly money," "liberty money," "mess money," etc.; greater precautions should be taken against the awarding of unjust punishments; a practicable appeal from arbitrary decisions of commanding officers should be provided for; and last, but not least, the firemen should not be required to do any more work than is absolutely necessary outside the engineer's department. They are, on the more modern ships, the hardest-worked men in the ship's company, being employed from early morning until late in the afternoon overhauling and repairing machinery; and after this work is done they are exercised on deck in evolutions in which they could not possibly participate in action, as they would then be all required at their legitimate work below.

Then, again, besides getting trained men, we must have more men. The Colossus, which the author quotes, worked 35 "stokers" in the "stokehold" when she made her 7488 I. H.-P., or one fireman for every 214 I. H.-P. At this rate the Atlanta should be allowed 17 firemen on each watch in the fire rooms, supposing that she had as good coal as the Colossus; but with Cumberland coal the extra amount of work would necessitate the employment of 20 per cent more men.

Men accustomed to working fires only under natural draught are at first almost useless on forced draught fires, and not only require training, but they must be kept in condition by constant practice. The severity of the labor on forced draught fires increases much more rapidly than in the same ratio as the I. H.-P. It is only too probable that ships after running their full-power trials will never again use forced draught except in case of emergency, and then the firemen will be found wanting, for lack of practice. Forced draught should be used, on a portion of the boilers at least, for a part of every run, and every ship should have a twenty-four hours' full-speed run at least once a year, to bring the men up to as near the proper standard as possible.

But I must ask to be allowed to digress from the main subject to take exception to the author's comparison of our I. H.-P. per square foot of grate with that of various English ships. In the first place, it is idle to suppose that with Cumberland coal we can get as good results as those obtained from Nixon navigation coal. In Mr. F. C. Marshall's recent article on high-speed marine engines, he gives the results of trials of both Nixon and Cowpen coals in the

same boiler. The Nixon coal evaporated 8.57 pounds of water from and at 212° F., while the Cowpen coal (corresponding to our Cumberland) evaporated but 6.97 pounds. Besides this, our coal contains considerable ash, while the Nixon coal is so clean that the English ships run their full-power trials without hoisting ashes. The author's reference to the expected I. H.-P. of the Nile is unfair in another respect, as she has triple-expansion engines, while the Atlanta's engines work with double expansion, and so the increased performance per square foot of grate is in part due to the more recent design of the engines, and not to better firing.

And here, too, I must protest against the now too common practice of comparing the official results of our trials with the newspaper reports of the trials of foreign ships. For a long time I put implicit confidence in reports of trials which appeared in leading engineering papers, but I have found so many of them false that I have come to such a state of incredulity that I am loth to believe any reports whatever unless the strongest proof of their correctness is furnished.

Experience has taught me that men ordinarily of the highest integrity regard the horse-power of their engines as a perfectly legitimate subject for exaggeration, and would no more hesitate to romance on this subject than would an angler on the weight of his catch, or a mountaineer on the length and girth of various snakes which form the themes of stories which he loves to narrate to open-mouthed and credulous listeners. This practice is of no sudden growth, but has gradually developed. One man shows his engine to make a certain economical performance, and his neighbor, to keep up his reputation, must needs beat his record; and so it goes on until those builders who would like to give truthful accounts of their trials are afraid to do so because they would appear to be behind the rest of the world. All sorts of tricks are resorted to, but the principal ones are the use of over-rated indicator springs, and increasing the speed at the moment that the indicator diagrams are taken. Let me cite an example: Within the past year there was received at the Navy Department a set of indicator diagrams from the triple-expansion engines of one of the finest steamers in the Trans-atlantic service. Here, thought I, was some data about triple expansion that was worth having. The engines were designed by one of the most eminent of English engineers; the ship and machinery were built by a famous firm on the Clyde; and the ship is owned and run by one of the best companies whose vessels ply the Atlantic. There was no need for deception here: the reputation of all parties concerned was too firmly established to need any such assistance; but need I say that my faith in human integrity went down to the lowest ebb when the first application of the given indicator scale showed *seven pounds more initial pressure in the high-pressure cylinder than the pressure in the boiler?* Probably they had counted on nobody being inquisitive enough to examine into such unimportant details. These engines were said to develop a horse-power on 1.32 pounds of coal per hour, but the power actually shown by the diagrams (without any correction of the scale) proved that these figures were entirely too low, as the consumption of coal per day was known from the ship's log. Going a little further, I compared the revolutions at the time the

diagrams were taken with the ship's run for the day, and found that the cards were a set of "show cards" taken with the engines running at considerably more than their average speed. This brought the cost of the I. H.-P. still higher. But I was not content to stop here: the indicator must be made to bear still more testimony against itself. Now, no matter to what unknown extent an indicator scale may be falsified, and no matter whether or not we know the correct number of revolutions, there is an unfailing test that may be applied. As the specific weight of steam varies almost directly as the steam pressure, the ratio between the weight of steam shown by any given indicator diagram and the work shown by the same diagram will be very nearly constant, no matter what may be the scale of the indicator. Applying this test to the diagrams in question, I found that they showed 14.76 *pounds of steam per I. H.-P. per hour*, no allowance being made for losses. It would take a phenomenal boiler, excellent coal, and better water than we have on this side of the Atlantic, to make this amount of steam without the expenditure of a great deal more coal than the quantity claimed.

Another case very similar to this was the trial of the quadruple-expansion engines of the Rionnag-na-Mara, where the cost of an I. H.-P. was said to be 1.125 pounds of coal per hour (vide *Engineering*, April 9, 1886). An English engineer had the temerity to question the accuracy of the trial, and showed that the indicator diagrams accounted for about 14 pounds of steam per I. H.-P. This brought down upon him the wrath of several other engineers, one of whom made himself ludicrous by accusing the critic of unfairness in taking his measure of the steam where the diagrams showed a maximum quantity, instead of from the point where the least steam was indicated.

Going back several years, I may cite the trials of U. S. S. Vandalia and H. M. S. Garnet, which are tabulated by Brassey in Vol. I. of "The British Navy." The Vandalia, at 2033 tons displacement, burning anthracite coal, made 12 knots per hour on 1200 I. H.-P. The Garnet, at 2120 tons, burning bituminous coal, made 13 knots on 2000 I. H.-P. Both ships had the same area of grate surface. By Froude's law of comparison, the corresponding speed and power of a vessel on the Vandalia's lines, but with the displacement of the Garnet, would be 12.08 knots on 1263 I. H.-P. The I. H.-P. for this ship at 13 knots would then be, by a simple calculation, only 1575, instead of the 2000 said to have been made by the Garnet. The two ships are fairly comparable by this method, as their coefficients of fineness are practically the same. But if the published reports of the Garnet's trial are correct, she must have somehow wasted 2000 — 1575 = 425 I. H.-P. I am inclined to think, however, that no such careless engineering was done by her designers and builders, and that the horse-power was exaggerated in the reports made public.

There are many still earlier indications of this tendency to give incorrect reports of engine trials. It is now nearly a quarter of a century since Dupuy de Lôme publicly remarked that it required more power to drive English ships than French ships of similar size at similar speeds, and attributed this to the finer lines of the latter ships. This aroused the ire of the English shipbuilders; they scoffed at the idea of Frenchmen producing finer models than theirs,

and in order to prove their position they were compelled to virtually acknowledge that the increased horse-power was due, not to the greater resistance of the hulls, but to the less resistance of the indicator springs.

We often hear of trials of very short duration, but they seem to be considered by many people to be of the same practical value as longer trials of other ships, and are quoted on terms of equality with them. For instance, the performance of the Naniwa Kan is frequently compared with that of some of our ships. She is reported as having made 7650 I. H.-P., or at the rate of 19½ I. H.-P. per square foot of grate. Her trial took place over a course of 9.6 knots, one run being made in each direction. The first run, with the tide, was made very nicely indeed, but the run against the tide was not so successful. Before two-thirds of the course had been passed over the steam had run down from 90 to 72 pounds, and the revolutions from 123 to 117; and here the reports of the trial abruptly end. And now it turns out that during these short runs *no water was fed into the boilers*, the trials beginning with water at the tops of the gauge glasses, and ending with no water in sight. The unfairness of comparing such a trial as this with a carefully conducted six-hours' trial must be patent to all.

These are but a few instances which I might mention where the public has been deceived by false reports of trials. The great trouble about the accounts of most trials is that sufficient data is not given and the results cannot be analyzed.

I must apologize for having made this long digression from the subject of the paper under discussion; but I have seen so many proofs of gross exaggeration in published reports of foreign engine trials that, the author having referred to some of these trials, I could not resist the temptation to show the character of some of these reports.*

Passed Assistant Engineer BAIRD.—*Mr. Chairman and Gentlemen*:—I am much gratified to see the subject of training the engineer force brought before the Institute, particularly at this time, when new and powerful steamships are being added to the Navy. The problem of training this force is not new; those

*Since the above was put into print, the Alliance, using ordinary steaming coal as it came from the bunkers, has made a maximum performance of 12.4 I. H. P. per square foot of grate, and a mean of 11.1 I. H. P. per square foot of grate *for a ten hours' run* on regular service, with apparent ability to keep up the same performance indefinitely. This, however, cannot be fairly compared, on a grate-area basis, with the performances of the English ships, as the Alliance's boilers were designed and built for natural draught only; the forced draught having been introduced at the last moment in order to test a new system of applying the blast. And not only were her boilers not properly proportioned for forced draught, but she was using steam of only 78 pounds pressure in engines designed fourteen years ago and in almost constant use for the past twelve years, while all the foreign ships which are reported to have made such superior performances use much higher pressures in engines of the very latest design.

In order to show that I am not alone in condemning the reputed performances of foreign ships, and in deprecating comparisons between them and our own vessels, let me quote from a late number of one of the leading English service journals (*Admiralty and Horse Guards Gazette*, April 16, 1887, page 242): "We are strongly opposed to the present system in regard to the steam trials of Her Majesty's ships. *As criterions of speed they are perfectly useless and utterly delusive.*" A. D. M.

of us who came into the Navy in the days of side-wheel steamers with jet condensers, and have served through the changes that have passed, have witnessed and have taken part in various organizations, methods, and experiments in the matter of turning our force to the best advantage. There was a time when our force was a good one.

Before touching upon the points so well expressed by the essayist, I beg leave to recall, as a matter of history, some of the forms of organization through which we have passed, that we may be the better able to arrive at a choice, by preventing a repetition of what has worked badly. When I entered the Navy of the United States, during the War of the Rebellion, there was a large number of engineers in the Navy, particularly in the lowest grade of the corps; there was also a large number of merchant-service firemen enlisted in the service. On board large ships the fire room was in charge of a junior engineer, who also 'tended water; the rule was at that time to run the ships at full speed, and to force them frequently; the engineer force was accustomed to urging the fires, and the men either became skillful firemen or broke down completely in a short time. Discipline was at that time good; a commendable emulation existed between the watches as to which should excel in revolutions, and it was at that time conceded that the best result depended more on the engineer in the fire room than on his senior in the engine room. He was the fellow who handled the men; he was the fellow who was looked to "to get the steam." With this in view, and a hope of promotion (which was rapid at that time), the young engineers were stimulated with a desire to inform themselves as to the best method of managing fires and *managing men*. They quickly learned to utilize the men to best advantage, and the men readily learned to work to each other's hand.

The firemen were rarely called upon to perform any duty on deck, and seldom complained of overwork in the fire room, so long as the division of labor was equable. The engineer force was divided in a way to do "the greatest good to the greatest number." When all hands were called to quarters, the watch in the fire room remained there, the first relief went to the steam-pumps and hose, and the second relief to the powder division. The advantages of this distribution are evident. The force was at that time considered as belonging exclusively to the engineer's department, except at quarters, when a part of his men served in the powder division. A boat's crew or a landing party of firemen was always under an engineer; there was no mixing of the men from the several departments of the ship; the engineer's department was then managed very much as on board a merchant steamship.

At the end of the War of the Rebellion the Navy Department began to economize by reducing the number of men in the ships, by placing restrictions on the use of coal and enforcing greater use of the sails. A regulation still exists which forbids the commanding officer from sanctioning more than two-thirds the steam power being used except in cases of emergency, on which occasions he is required to make a special report to the Navy Department. Nor is the two-thirds power defined; it is not known whether the Navy Department meant two-thirds of the power of the boilers when new, or two-

thirds of the power of the boilers as then existing. It is interpreted in more than one way, and on the construction put upon this regulation sometimes depends the reputation of a vessel for speed. I made a cruise on board a gunboat just after the close of the war, when this regulation was new. The vessel was provided with blowers for forcing the fires, which would increase the rate of combustion more than 50 per cent. With these blowers in operation a power of almost 1500 indicated horses had been reached, and a speed of 13½ knots had been exceeded. The vessel had been in use two years, and the boiler pressure had been reduced somewhat; the question arose as to what was full power and what was two-thirds power; the decision—on board the ship—was "all we can get with eight-tenths of the furnaces with natural draught," which resulted in the development of about 800 indicated horse power and a speed, in smooth water, of 10 knots per hour. During all my years of sea service since that period I have seen but one United States Navy vessel run at full speed for an hour.

Not only are we prohibited from exceeding two-thirds the power, but admonished to be exceedingly economical in the use of coal; in fact, I have known the limit of coal per hour to be so small that the problem was to prevent the fires going out entirely. To economize still further, the Navy Department, about the year 1870, abolished the firemen and substituted seamen-extra, ordinary seamen-extra, and landsmen-extra, in lieu of first-class firemen, second-class firemen, and coal-heavers, respectively. The purpose was to sail the ships, using steam to enter and leave port and in emergencies. To accomplish this more fully, the sail area of many vessels was increased; barques were changed to ships, and royals were provided to vessels which had hitherto had nothing above topgallant sails; and that the drag of the propellers might retard the vessel's sailing less, two-bladed screws were substituted for four-bladed ones,—and it was believed that the Navy would be greatly benefited. At this time the junior grade of engineers was abolished, reducing the engineer corps about 50 per cent. The ships could not, therefore, have an engineer in the fire room; in fact, it sometimes occurred that no old fireman could be found among the seamen-extra (who were detailed from the deck when we got up steam), and there was sometimes difficulty, if not danger, in the matter of 'tending water. Of course it was an admirable arrangement for wasting fuel, but as the ship sailed most of the time, this loss was not so great as might be expected. The men being shipped as seamen, etc., were no part of the engineer's force; when they worked in his department it was on a temporary detail, and the same men were not always detailed, so that "training" was out of the question.

The Navy Department, in its wisdom, recognized the mal-organization and reinstated the firemen in their original ratings and wages. The rating of machinist was substituted for that of junior grade of engineer: it had many advantages, but more disadvantages. The ratings of boilermaker, blacksmith, and coppersmith have been created, and though found desirable, the two latter have for some reason been discontinued. The short-handedness of the crews still exists to such an extent that "emergencies" requiring the assistance of the firemen and coal-heavers on deck are rather the rule than the exception. But

with the labor-saving machines—steam windlass, steam hoisting engines, steam steerers, steam ash hoists, etc.—now being generally utilized, as well as the diminished sail area which is being introduced into the ships of latest improved design, we are inspired with a hope that we may again have a division in fact, and an opportunity to train it.

I beg, however, to differ with the essayist in regard to his comparison of results reported from British trials and those made by our own people. Our experience with an air tight fire room commenced with Mr. Dickerson's design of the machinery of the Pensacola in 1861. It was a failure. With the blowers doing their utmost on board the Atlanta, the pressure in the fire room was $1\frac{1}{10}$ inches of water. To obtain a more rapid combustion, and greater power from the same boilers, these machines will require to increase in power in a higher ratio than does the rate of combustion, on account of the increased leakages; and to obtain the powers claimed by our transatlantic cousins, the figures reach doubtful proportions. The practical difficulties of the air-tight fire room, and the advantages which appear in the Bureau's design of the blast in the Newark, will probably lead to the general adoption of the latter, which, if developed, may put those gigantic powers within our reach. By the use of the blower, our regular navy ships developed as high as 7.57 horse power per square foot of grate surface, during the early years of the war. When the boilers of these vessels were worn out they were replaced by boilers of equal size, *but without the blowers*, and of course the vessels were not as fast, nor could their machinery develop as much "horse power per square foot of grate."

So far as the power developed by the foreign ships is concerned, I must say I do not believe the reports are correct, for the reason that, for the same speed of a given-sized vessel, they report a much higher power than do the French or Americans. The French people raised this doubt before we did. Nor is this exaggeration confined to their Navy. In 1872, when I served in the South Pacific, there appeared several large new screw steamships belonging to the P. S. N. Co. These vessels had compound engines, for which an extraordinary economy was claimed. I visited many of these vessels, and, though never permitted to see their log book, I was given great facilities for examination. The speed of these fine ships and the power developed by their engines, as calculated from the indicator diagrams, balanced very well, but the amount of coal said to be consumed made it appear that an indicated horse power was developed for less than a pound and a half of coal per hour. Of course I did not believe it, though I was sometimes placed in a position which made me feel like the twelfth man on the jury who "never saw eleven such unreasonable men in his life." Later on, however, we obtained from the commanding officers of these vessels extracts from the noon reports of the engineers, which showed a consumption of 55 tons of coal instead of 36, which brought the horse power up to $2\frac{1}{8}$ or $2\frac{1}{4}$ pounds of coal per hour. The unit of measure of the economy of these vessels was in tons of freight per pounds of coal; the comparison of the new engines of war vessels to-day is in indicated horse power per pound of weight: the com-

petition is sharp; the reward is great. There is no doubt about the powers having been enormously increased for a given weight of engine, but I believe the reports from the other side of the water to be greatly exaggerated. By a weak spring in the indicator, or by other jockeying, the power may readily be exaggerated. I am informed that the reports of the trials of British war vessels are not signed by any one; if this is the case, who is responsible for their correctness?

There is probably not a single engineer in the Navy who is not convinced of the necessity for trained men in the fire room, particularly for the vessels now building. I am satisfied that if a man has endurance, weight, and "gumption" he may become as good a fireman in three months as in three years. There is an art in firing, as in every trade, and it is by no means the man who labors hardest that gets the most steam. It is, however, nonsense to put a boy or a light man at a heavy fire; such may be utilized in the engineer's department in many ways, but not at the fires. A boy, if possessed of gumption and good habits, may soon be trained to run a steam launch, or to oil, and will soon become a "handy man" in the engine room. The lifetime of a fireman has been variously estimated at from three to nine years (about the same estimate has been put on puddlers, whose work is before a hot fire)—perhaps a mean, or six years, would be a fair estimate of the duration of this craft or trade; it is evident then, if we are going to get good results from our men, we can afford but little time for "training," so must select good, hardy material, and combine the training with useful work. To have an efficient watch of firemen, it is essential to have a man over them who knows how to regulate them, and who can enforce his orders. The men should not be permitted to shift watches, but the same men should be kept together, that they may know each other's ways and work to each other's hand. The firing of furnaces in sequence is essential to economy and to high results. The order of cleaning the fires has an importance which must not be overlooked. The watch in the fire room should know what fires are to be cleaned by the succeeding watch; there should be an hour for cleaning each fire. These are about all the general points that can be given. The engineer and the water tender are dealing with problems of nature; the elements are constantly varying, and they must shift their constituents, sacrificing one if they would produce another.

It would be much better, on board our war vessels, if the chief engineers had more control of their divisions, and had the same authority over their enlistment as on board merchant ships. As at present practised, the enlistments and discharges of firemen are made by another officer, and on the discharge a fireman's "proficiency in rating" is estimated by a line officer who necessarily has not the means of personally knowing the merits of that qualification. The small discharges of firemen bear the signatures of several officers, but never that of the chief engineer. On board a merchant steamship the chief engineer has all to say about the liberty of his firemen; on board the ships of the Navy it is not so. It is the custom, by the courtesy of the executive officer, to consider the liberty of the firemen recommended by the chief engineer, but the

[illegible] has [illegible] the same [illegible] the former [illegible] the firemen.

[illegible] are probably [illegible] the merchant service, though [illegible] and work on deck. [illegible] advantage of the chance [illegible] of time; when the [illegible] his working clothes, [illegible] "mess gear" piped and [illegible] interfere seriously [illegible]

[illegible] ships faster and their [illegible] exclusively to the [illegible] gallant and royal yards [illegible]

[illegible] *and Gentlemen*:—Mr. Parks' [illegible] the Navy—a need never felt so much [illegible] become still more imperious. [illegible] chiefly, and some entirely, [illegible] these vessels must have effi- [illegible] forgotten that any renown gained by [illegible] their having efficient ships and crews [illegible]

[illegible] of the engineer's force trained [illegible] school ships; but I think Mr. Parks [illegible] needed by about two-thirds of the force. [illegible] and coal-heavers are easily learned. What [illegible] is a very moderate amount of skill, combined with [illegible] discipline. And it is here that we are most [illegible] engineer officers I have heard but one opinion, [illegible] in our engine rooms has been steadily deterio- [illegible] year 18[illegible], when the ratings of firemen were abolished, [illegible] created in their places. Although the ratings have been [illegible] increased, the discipline has continued to become worse [illegible] I attribute to the fact that the control of the men of the [illegible] has been more and more withdrawn from the chief engineer— [illegible] held responsible for the department in which they serve, and [illegible] direction they are supposed to work. Now, it is no uncommon

thing for machinists or firemen to be given leave to go on shore without the knowledge of the chief engineer, and without reference to the work in the engine or fire rooms on which they may be engaged. And it frequently happens, almost daily in fact, and sometimes more than once a day, that the whole engineer's force is called off from its work and sent on deck to help to spread awnings, furl sail or the like, the fire room being cleared by the master-at-arms. This is ruinous to the discipline of the engine room. The men, seeing that their duties below are thus made of secondary consideration to sail drill or other evolutions of that kind, come to regard them as secondary, and cease to take that interest in them which they otherwise would do. Seeing, too, that their liberty on shore, monthly money, and other indulgences depend in no way on the manner in which they satisfy the chief engineer by their skill and zeal in the performance of their duties, they have come, as a rule, to have little regard for the approval of that officer, and they will carry out his orders in such way as may be easiest and most convenient to themselves.

Every ship's company should be moved and actuated by one will—that of the commander. The commander's command is general, and he handles his ship and crew through his executive and divisional officers. In battle, or at quarters, and at all other times, the officer who is in charge of any subdivision of the ship's company, and who is responsible for their performance of duty, should be to those men as a commander, and his orders should be obeyed by them with as much alacrity as if they were issued by the commander in person. This is especially desirable in the case of the engine-room force, as in battle their duties are performed under the eyes of the engineer officers alone, and they will lack the stimulating effect of the observation of the commander.

Only those who have spent some time in a modern fire room where a forced blast is used can appreciate the strain on the physical and nerve powers of those there employed. The heat, even in a temperate climate, is apt to be excessive, and the working and cleaning of the fires will task the strength of strong men to the utmost. And I have seen men of a good deal of experience as water-tenders unnerved by the violent fluctuations of the water level in boilers where the combustion and evaporation were being pushed to the highest limit. Under circumstances like these, the highest degree of discipline is imperatively demanded as the only price of efficiency.

To improve and establish the discipline of our engine rooms, I suggest the following changes:

1st. Liberty on shore and other indulgences to be asked and granted only through the chief engineer.

2d. The men of the engineer's force who may be employed in the engine or fire rooms not to be called thence during working hours, for any routine drills or evolutions except general or fire quarters.

3d. Instead of having the firemen drilled at small-arms, etc., on specified days of the week, have them drilled so many times a quarter, the chief engineer to arrange the times so as to interfere as little as possible with the work under his charge. Under this arrangement, the men would get more drills than they do now, as under the usual system drills are often omitted on account of pressing work in the engine room or unfavorable weather.

... at least abreast of the times, and face to face ... greater speed for our big ships, as well as for ... the least possible consumption of fuel. In order to ... force on board ships must be possessed of a ... than that usually found among the firemen, and ... duty, which is new and varied.

... commenced in one of the training ships, and after two ... be ready to send to a cruising vessel to complete ... should be shown the same consideration as other

... be called after morning quarters (this call includes ... worked on deck until seven bells; then after dinner the ... around and amuse themselves as they wished, ... would be required for work in the engine department ... respond to another call of "all hands send down

... good one: but boys under 17 years should not be ... on the term of service the chief engineer of the ... person to decide whether or not the man or boy in

JARVIS B. EDSON, M. E., of New York.—*Mr. Chairman and Gentlemen*:—Professor Tyndall has somewhere told us that we need but walk through the shops of Woolwich, or any of the great factories where steam is employed, to become impressed with the magnitude and extent to which heat, manifested in the form of steam, becomes a helpmate to mankind. But I think if he had, for his illustration, suggested a sojourn in a modern vessel of war, with its mighty engines for propulsion and its innumerable smaller ones for almost every conceivable purpose, and had seen its mighty furnaces giving life, activity and success to the whole, he would certainly have commended it as a somewhat fitting exemplification of his "Heat as a Mode of Motion." Do not fear that he would have contemplated the machinery to the neglect of the coal pile, with its theoretical, dynamical efficiency, or to the neglect of the all-important question as to how the proper combustion of this legacy of the carboniferous epoch was effected. To him each unit of coal would have represented a certain amount of stored-up energy, theoretically valuable according to its composition, and practically valuable according to the distance it had travelled from the mine added thereto. To such a mind frugality is but the natural outgrowth of a knowledge of the article and of its possibilities, and to misuse or to waste that upon which much may depend, would be to him as though a man bound for the Arctic regions were to be wasteful of his provisions from the outstart, forgetting the important fact that their value increased rapidly according to the distance carried and quantity remaining.

Were such intelligence to be found in the material from which firemen are made, even then skill born of experience would be required to constitute a competent fireman.

Certainly no defense can be found for the almost indifferent manner in which coal is left for ignorance to convert into useful effect. Such a thing as the proper combustion of the coal, and its conversion into the utmost heat possible, and how to reach the best results, receives but the most meager attention from the engineers of the present, and none whatever from the men whose ignorance prevents their even caring. Frugality, if ever approached, ends whenever it becomes necessary to limit the consumption of pounds per diem; while the pounds per horse power developed per diem are hardly considered, if at all. Employes of almost any other class might be either ignorant or neglectful without necessarily causing serious accident to follow; but when such a one becomes the custodian of such a magazine of energy as a steam boiler, active intelligence is demanded both for safety and economy, and no man should ever be allowed in any important position in connection with the operating of boilers unless fairly well conversant with the subject. Because a man is a fireman, does it signify that he shall be nothing but muscular development and incapable of instruction? That men should be thoroughly fitted for and trained as firemen seems as self-evident, so far as the matter goes, as the necessity that men should be trained for engineers before being allowed to act as such. How they are to be best fitted for such duty may admit of many solutions, but certainly is it true that it will repay the Government well in the fuel saved alone, for any expense likely to attend the proper instruction of its

firemen. Ten to twenty per cent of fuel saved daily may represent many dollars during a year's steaming, and men effecting such economy may well receive a rating and compensation somewhat in accordance therewith. It would seem that the proper place for the instruction in such duties would be on board of vessels while not otherwise engaged, and steaming for the express purpose of affording practice and instruction to a set of men, who may be the operatives, and in the presence of others who may be receiving instruction, as witnesses. With a constant load on the boilers, in the way of certain revolutions per minute, competitive runs of four hours each would go far toward determining the skill with which an experienced man would compare in the consumption of fuel for such period with those under instruction. In some such way would men soon learn to appreciate the subject of proper combustion, measured in terms quite comprehensible to them, such as the distance made and the revolutions of the engine effected.

While this special instruction is to be commended, it does not, in my opinion, necessarily follow that efforts should not be made in the same direction on board of every naval vessel, while under steam, on the part of the engineer force accompanying the same; because, while perhaps not so rapidly, but quite as effectually, can men become qualified in the regular practice of the service. Professional pride on the part of the engineer of the watch should certainly demand that he pay the attention necessary to the end that the coal with which he is provided should be properly used—used as though it were paid for by himself—so as to get the utmost efficiency from it. In the ordinary practice on land no such favorable opportunity can be obtained for the practice of frugality under intelligent management, but in the Government service great opportunity exists for the proper edification of the men in the fire room as to the proper methods of firing with the various kinds of fuel provided them. I consider the object of the paper of the evening of great value, as the subject is too commonly overlooked just where much better results should be looked for; and if provision is made for teaching men how to fire, they will be encouraged therein, well knowing that, after their enlistment expires, they will stand a better chance of finding employment on shore at more than laborer's wages.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

MAY 11, 1887.

COMMANDER C. L. HUNTINGTON, U. S. N., in the Chair.

# IRON AND STEEL, AND THE MITIS PROCESS.

BY W. F. DURFEE, M. E.

*Mr. Chairman and Gentlemen:*—I am announced to speak to you this evening upon "Iron and Steel, and the Mitis Process"—a subject manifestly too vast to be discussed comprehensively in a single lecture.

I shall, therefore, confine my remarks, relative to iron and steel, to certain observations and conclusions made during a somewhat intimate practical acquaintance with these metals for the past thirty years, which I regard as contributing to a correct understanding of their structure, and to their proper treatment in the course of manufacture. I shall then, in conclusion, offer a description of a recent and most promising improvement in the metallurgy of iron and steel called the "Mitis Process."

Allow me first to endeavor to answer the question, "What is wrought iron?" One of the greatest obstacles to a correct apprehension of this question is this:—the way in which a mass of wrought iron is built up is not generally well understood, and the difference of its structure from that of a homogeneous material is not fully comprehended. The term wrought iron is popularly supposed to designate a metal; but it is really the name of a mechanical admixture, which, at its best, consists of clusters of crystals (which may with propriety be regarded as compound crystals) of pure iron separated from each other, as the result of the manipulative processes employed, by films or threads of an unavoidable impurity called "cinder." In the manufacture of wrought iron, the "pig," or other variety of cast iron, is first deprived, in a more or less imperfect

degree, of carbon and other impurities, by what is known as the "puddling process." This process may be briefly described as consisting of four distinct operations; viz.—

1st. The melting of the "pig iron."

2d. The "boiling" of the melted metal in a bath of liquid "cinder" (composed mainly of silicate of protoxide of iron), until the iron (which, owing to its loss of carbon and other impurities, can no longer remain fluid at the temperature employed,) begins to solidify in the form of small granules or crystals, which can be seen moving amid the boiling "cinder" like white-hot peas in a red-hot soup. When the iron begins thus to granulate or crystallize, it is said to be "coming to nature."

3d. The collection by the puddler of these granules or crystals into distinct masses called "balls." These contain much "cinder."

4th. The "squeezing" or "hammering" of these "balls," while still at a welding heat, into more solid masses, which are called "blooms." These contain much less "cinder" and other impurities than the "balls," but are far from being uniform in structure.

The "balls" above named may with propriety be regarded as white-hot sponges of iron saturated with liquid "cinder," which fills all their accidental and irregular cavities.

When the "balls" are "squeezed" or "hammered" (this last operation is often termed "shingling"), for the purpose of expelling this "cinder" and welding the granules or crystals of iron into a homogeneous mass, the attempt is never wholly successful; for the "cinder," as the metal cools, quickly assumes a pasty consistency and flows with difficulty, and all that portion of it inclosed in the interior cavities of the "ball" is simply flattened out or elongated. Hence it will be seen that the "bloom" is composed of a compacted mass of granules or crystals of iron, separated from each other by films or strings of "cinder" of very irregular dimensions.

When speaking of crystals of iron, I mean minute ultimate units of that metal, bounded by well-defined planes, whose intersections always form salient angles. A number of such crystals may cohere and form an aggregation, having bounding planes similar in outline and relative arrangement to those of any single crystal. Such aggregations, or compound crystals, vary in size, and are often regarded as single crystals and spoken of as such, just as we speak of crystals of galena or calc-spar, when, as a matter of fact, the ultimate crystal of each of these substances remains undiscovered, and as undiscoverable ...undaries of space.

These large or compound crystals of wrought iron are, in themselves, practically homogeneous: that is to say, the ultimate crystals of which they are composed are not separated and kept apart by any foreign substance, but are as nearly in actual contact as the law of cohesion, in obedience to which they are formed, will admit.

Now let us see how a "bloom," the crudest form of a mass of wrought iron, differs in structure from the homogeneous compound crystals of which it is chiefly built up. Such a mass of wrought iron is an aggregation of an indefinite number of such compound crystals as have been described, which are separated from each other by films or threads of "cinder" of very variable thickness; but which, notwithstanding, are mutually attracted with a greater or less degree of force, the minimum value of which is the measure of the cohesive strength of the mass.

Now let us follow the "bloom" as it progresses towards the form of a commercial bar of wrought iron, and examine carefully the structural changes which take place during such progress. When a properly heated "bloom," or other similarly constituted mass of wrought iron, is subjected to the action of the "hammer" or "rolls," the contained "cinder" endeavors to escape from its entangling alliance with the crystals of the iron, and in so doing, each particle thereof is driven into some line of least resistance, which is always finally located in a plane at right angles to the direction of the force acting upon the metal. In other words, if the "bloom" is rolled or forged into a rod or bar, the metal will be acted upon in two directions at right angles to each other,* and its compound crystals will be compressed in directions normal to the exterior surfaces of the bar, and at the same time extended in the direction of its length. Thus the ends of adjacent crystals are forced towards each other, and the intervening "cinder" is compelled to move at right angles to the axis of the bar, and to unite with the films or threads of "cinder" which have become established in parallel lines of least resistance along the flanks of the compound crystals, and at right angles to the direction of the force acting upon the bar.

Fig. 1 is intended to illustrate on an exaggerated scale this arrangement of the elongated compound crystals of iron with intervening

* In forging a bar it is the usual practice to turn it about its axis through an angle of 90° between the blows (or series of blows) of the hammer; and in rolling a bar it is commonly turned through the same angle between "passes" through the rolls.

films or threads of "cinder," the light spaces representing the iron crystals and the dark lines the "cinder"—the force of compression being supposed to act upon the bar in the direction of the arrow.

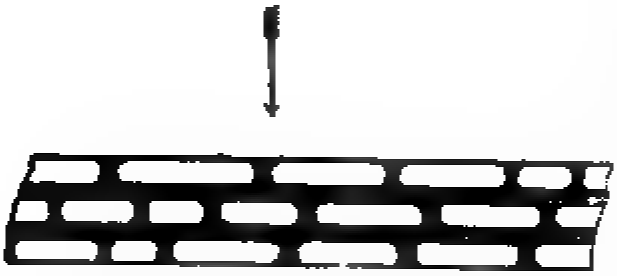


FIG. 1.

Fig. 2 illustrates a method of showing by experiment the character of the structural difference between a bar of wrought iron and one of a homogeneous material such as low steel. In this figure, let *A* be a vertical section of a cylinder provided with an accurately fitted plunger *P*. The space *B* below this plunger we will suppose to be filled with small fragments of lead of irregular dimensions, whose surfaces are covered with a coating of oxide of lead.

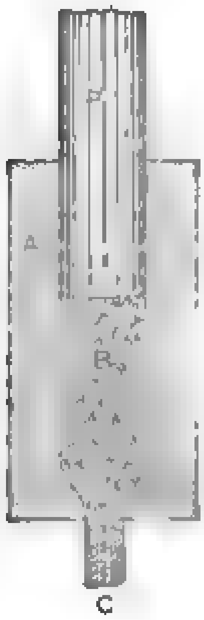



FIG. 2.

If, now, sufficient force is applied to the plunger *P*, the lead will be forced out of the hole in the lower end of the cylinder in the form of a rod *C*, and every fragment of lead will have become more or less elongated, but will be prevented from actual metallic contact with adjacent fragments by a film or thread of oxide of lead. In this experiment, the elongated fragments of lead correspond to the extended compound crystals of iron before named, and the oxide of lead occupies the same relative position in the rod of lead as the "cinder" in a bar of wrought iron. If now, in place of the fragments of lead, we place in the space *B* a solid mass of that metal, then, on applying adequate force to the plunger *P*, there will be forced through the hole in the bottom of the cylinder a rod of lead, whose structural difference from the former rod, made from the oxide-covered fragments, is closely allied to that subsisting between a bar of low steel, and one made of the "cinder"-coated compound crystals of wrought iron.

The direct consequence of the elongation of its compound crystals and the effort of the intervening "cinder" to escape in the direction of least resistance while the wrought-iron "bloom" is being forged or rolled as before described, is the establishment of that structural peculiarity in the resulting bar known as "fibre," which is one of the most conspicuous features of wrought iron, and one not found in any other variety of ferruginous materials.

When any of the films or threads of "cinder" in a bar of wrought

iron are so large as to be distinctly visible on its surface to the unassisted eye, they are called " sand seams " or " cinder cracks."

If its compound crystals are nearly pure iron, the bar can be readily bent cold without fracture, and, if pulled asunder by a gradually augmented force, its fibrous texture is at once evident; but in case the compound crystals have chemically combined with them some substance, such as phosphorus or silicon, which tends to diminish both the cohesive attraction between the ultimate crystals of which they are composed and the mutual attraction of the compound crystals, then the bar cannot be easily bent cold without rupture, and is said to have a " crystalline fracture." Notwithstanding this appearance, however, the mechanical structure of the bar is the same as before; that is to say, the " cinder " and elongated compound crystals are still arranged in lines parallel with the axis of the bar, although it is quite probable that the average length of the compound crystals may be much less than in the case of the bar first described.

Whenever a " bloom " is subjected to a force of compression always acting perpendicularly to the same plane, as is the case when it is rolled into a " sheet " or " plate," its compound crystals and accompanying " cinder " are each flattened and extended parallel with that plane, and the resulting " sheet " or " plate " has more of a laminated than of a fibrous structure, being built up of a number of leaves or strata of iron separated from each other by films of " cinder," which, when unduly thick at any point, cause defects in the plate that are called " blisters."

The foregoing discussion of the structural difference existing between a bar of wrought iron and one of homogeneous iron (often called " low steel ") naturally brings to mind an important practical question relative to the employment of wrought iron in construction which is often asked; viz., Will a given sample of wrought iron having a decidedly fibrous texture become crystalline under the operation of a continued repetition of violent strains or shocks? Doubtless many persons of large and varied experience will unhesitatingly answer this question in the affirmative. The sailor who sees his chain cable (known to have been made of carefully selected, thoroughly worked, and honestly tested fibrous iron,) snap short, has no doubt about the metal having become crystalline owing to lapse of time and rough usage. The practical farmer, as he examines a broken trace or plow chain, is firmly of the opinion that the iron

thereof had become crystalline by use. The railway passenger who has fortunately escaped serious injury from an accident caused by a broken axle, is usually ready to testify, with emphasized confidence, that "the iron of the axle was crystalline, and entirely unfit for the purpose for which it was used." A modern fiddle-string bridge goes down under a passing train, plunging a whole community in mourning and sending a thrill of shivering horror through the land—among the various theories advanced to disguise the utter want of sufficient intelligently distributed material in the structure, is sure to be found that of the crystallization of the iron employed.

But let us return to our question. Can a bar of wrought iron of a pronounced fibrous structure be ruptured so as to exhibit a crystalline fracture? I answer, yes,—in two ways. 1st. By a sudden application of a force of extension—commonly called a "jerk." 2d. By a prolonged repetition of a force of compression—sometimes called a "jar."

The first method of rupture may be said to consist of a transverse division of the compound crystals of the bar, as distinguished from a sliding of their interlocking flanks upon each other, as is the case when the rupture presents a fibrous appearance. I have often seen crystalline fractures produced in truly fibrous iron. In the manufacture of iron rails (now nearly an extinct industry), it was always considered desirable that they should be of a hard and crystalline texture as to their tops or "heads," but soft and fibrous in their bottoms or "flanges"; but however perfectly this distribution of metal was made, it was always possible to break a rail so as to show a crystalline fracture in its "flange." This was accomplished by making a slight "nick" across the flange (to determine the point of fracture), and placing the rail ("flange" down) in the "straightening press," on supports placed a short distance on either side of the "nick," and then putting in the "gag" "*heavy*," just over it: the result was almost always a crystalline fracture in the "flange"—in short, the elongated compound crystals were "jerked" asunder. But, if the points supporting the rail were placed further apart, and the rail given an opportunity to yield considerably between them, then, if the "gag" was put in "*light*," a number of times in succession, the fracture of the "flange" would be sure to exhibit a fibrous texture, due to the fact that sufficient time had been given to break up the films of "cinder" along the flanks of the compound crystals and their transverse cohesion, thus permitting them to slide apart, 
bit the appearance of disrupted fibres.

We are indebted to a not uncommon accident to which the hammer bars of a peculiar type of steam-hammer are liable, for an excellent illustration of the second method of producing a crystalline fracture in fibrous iron, the result of the repeated action of a percussive force of compression. In Fig. 3 is represented at *A* the bar of such a steam hammer. As has been before stated, there exist, in a bar of fibrous iron, films of "cinder" between the ends of its elongated compound crystals (as shown exaggerated in Fig. 1). These, from the nature of their formative process, cannot possibly be of uniform thickness. This, considered in connection with the fact that the greatest force of the percussive action per unit of area of any cross section of the hammer bar is exerted upon a section made by a plane cutting the bar at right angles immediately above its head, justifies the belief that at, or near, this point, fracture would be most likely to occur. It is also evident that the percussive action of the hammer would have more destructive effect upon thick than upon thin films of "cinder"; while, at the same time, the force of cohesion between the ends of adjacent compound crystals will be diminished in some inverse proportion to the thickness of the films of "cinder" between them. It therefore seems exceedingly probable that the fracture due to continued percussion will take place, if not in the plane above named, yet in one very near to it, in which the "cinder" films chance to be of greater thickness than those in that plane; and, as a matter of fact, fractures in such bars are usually within a few inches of the point where the bar enters its head, as at *G*, *H*, Fig. 3.

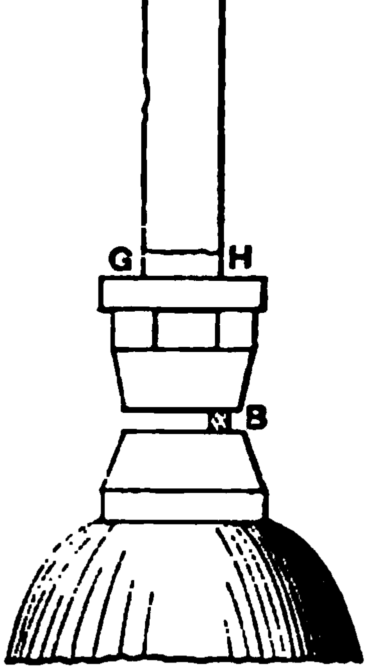


FIG. 3.

The particular point in the circumference of such a hammer bar where the imminent fracture first appears is often determined by the manual peculiarity of the "hammer-man." A left-handed man will incline his work to the left, and a man who is right-handed will be likely to use the right side of the anvil more than the left. In this latter case the work *B*, Fig. 3, will tend (whenever it is in the position shown) to produce a tensile strain at the point *G*, which, as the work is shifted to the centre or occasionally to the left side of the anvil, becomes a compressive strain. We should therefore expect (as is, in fact, the case) that the initial manifestation of the fracture

would be found at that point, and that it would gradually extend towards *H.* until the bar was finally "jarred" asunder. This separation would take place through films of "cinder" between the ends of the elongated compound crystals of the bar, thus exposing those ends, and exhibiting what is called a crystalline fracture.

The belief in this so-called crystallization of wrought iron, as the result of prolonged use, is, I think, altogether a mistake; and I am clearly of the opinion that the crystallization observed in the case of any particular fracture existed just as we see it at the time the metal was given the shape in which it was ruptured. After a bar of distinctly fibrous wrought iron has been subjected to multitudes of sudden "jerks" of extension or "jars" of percussive compression, the "cinder" in some cross section of it (in which this impurity is slightly thicker than elsewhere) gets broken up, cohesion is destroyed, and the bar breaks with a crystalline fracture.

I have had a specimen prepared for the purpose of making the foregoing explanation of the apparent crystallization of fibrous iron more evident. It is a short piece of a square bar of wrought iron. One end is decidedly crystalline in its fracture, showing distinctly that the bar was originally built up of five flat bars. The other end is, for more than one-half of its area, as decidedly fibrous as wrought iron can well be: and this end would have been uniformly fibrous in appearance had the workman who made the specimen exercised the requisite care. Thus, in a sample not over two inches in length, we have an instance of a fracture which most observers would call very bad, and another which as certainly would be called good.

It is a well-known fact that wrought iron is improved in strength by repeated working. This may be accounted for thus:—in the initial heating and shaping of the metal, its crystals were left with a comparatively thick film of "cinder" between them; but, by each successive reworking, the crystals of metal are driven into closer order, some of the intervening "cinder" is expelled, and what remains is very much reduced in thickness, so that the cohesive attraction (whatever that may be) between these crystals, having less space to act through, acts with augmented intensity. It is well to remember, when we speak of "less space" in a matter of this kind, that we are dealing with a very small quantity indeed—one that is a near approach to the infinitesimal.

Time presses, and though I could fill the fleeting hour with talk [illegible], yet in this lecture, as in the field of mechanical construction, [illegible] fitting that iron should give place to steel.

What is steel? To the many answers to this frequently asked question, I may perhaps venture to add this one more, namely, that steel is iron freed from mechanically mixed impurities (such as "cinder") by a melting process, during which it has combined with it chemically a small percentage (not large enough to prevent the metal being forged or rolled) of other impurities, introduced for the purpose of modifying its strength, hardness, elasticity, or ductility, in such degree as to adapt it to the particular use to which it is to be applied. In short, while wrought iron is iron having (as the legitimate result of the methods employed in its manufacture) its impurities mechanically mixed, steel is iron having (as the result of the adoption of appropriate manufacturing processes) its impurities chemically combined.

A great deal of the difficulty of correctly fixing the *status* of any given sample of ferruginous material may be eliminated by recognizing the fact, that what is called wrought iron is not really iron, and that the only way in which *pure iron* can be obtained is by electrolysis; a process which is, I need hardly say, commercially impossible for all practical purposes in the present state of our technical knowledge.

I cannot on this occasion describe at length the various processes employed for the manufacture of steel, but will call your attention to certain practical details which are of especial interest and importance.

If we break a large ingot of mild steel (say of 12″ to 15″ square) at right angles to its length, and examine the fracture, we shall find at a distance of from three-quarters of an inch to two inches from its sides, a collection of cavities or "blow holes" (as they are commonly called), which are of an irregular spheroidal form, and of variable size, the largest seldom exceeding one-half an inch in diameter. These holes are separated from each other by partition walls of irregular thickness, and in most instances are coated on their interior surfaces with films of a more or less iridescent oxide of iron. Fig. 4 will serve to give an idea of such a fracture as has been described.

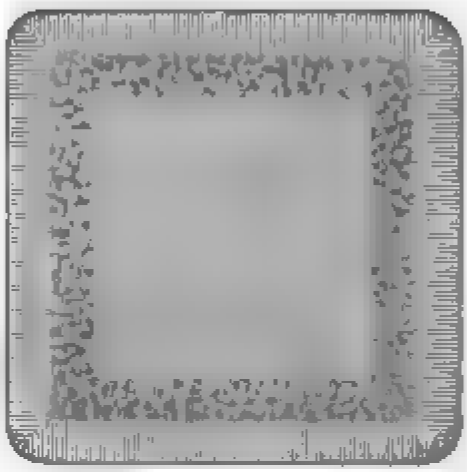


FIG. 4.

There has been a great deal of speculation as to the origin of this array of cavities. Some have supposed that they were caused by gases dissolved in the fluid steel (very much as carbonic acid is

My own explanation of the formation and peculiar distribution of these cavities is a purely mechanical one, which I will now endeavor to make clear.

It is a well-known fact that a vertical stream of any liquid descending freely through the atmosphere drags along with it, by frictional contact, a notable quantity of the air or of any other gas that may be in its immediate vicinity. This fact was many years since taken advantage of in the construction of the blowing apparatus called the "tromp," used for furnishing the blast for the forges of Catalonia.

This apparatus consists of a vertical pipe *P* (usually of wood), whose height is determined by that of the head of water at the locality of the forge; the upper end of this pipe passes through the bottom of the wooden race-way *R* (Fig. 5), and is closed or opened by the movable conical plug or valve *V*. Below the bottom of the race-way *R* there are several inclined apertures *a*,*a*,*a*, made in the sides of the pipe *P*. These are for the purpose of admitting air, which, when the valve *V* is raised, is drawn in by the descending column of water, and mixing therewith, is carried downward and discharged thereby into a receiving chamber *C*. Here a separation of the air and water takes place, the former passing through the tuyère pipe *T*, *T* to the forge-fire *F*, and the latter escaping from the receiving chamber through a hole in its side at *H*. The volume and pressure of the blast supplied can be regulated within certain limits by raising or lowering the valve *V*, by means of the cord *K*, acting through the lever *L*.

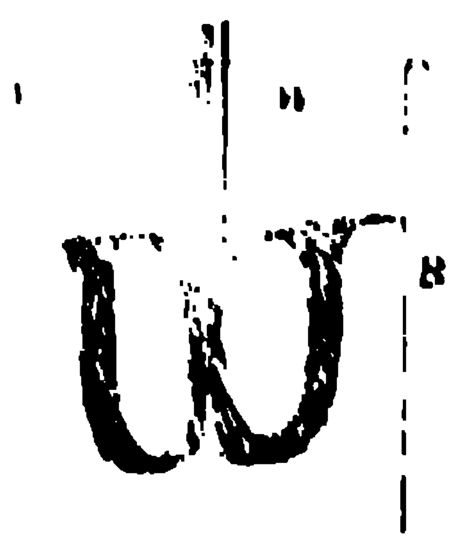
Over twenty years since (1863), I employed (in the laboratory of the experimental Bessemer steel works at Wyandotte, Michigan) the principle of the mechanism described for supplying blast for a table blow-pipe. The apparatus for this purpose consisted of an ordinary three-necked Woolf bottle *B* (Fig. 6) of about a half-gallon capacity, to the middle neck of which was adapted a cork through which was passed the stem of a small funnel *F*, which reached nearly to the bottom of the bottle. To the right-hand neck of the bottle *B* was fitted the discharge syphon *S*. The left-hand neck of the bottle *B* had fitted to it a bent glass tube *T*, to whose horizontal end was attached a rubber tube for conveying the air to the blow-pipe. To put the apparatus in operation, a stream of water was discharged from a jet-pipe *J* into the top of the stem of the funnel *F*. The diameter of this stream was slightly less than the internal diameter of the tube of the funnel, and could be regulated as regards its volume and

[illegible] as the stream of water from the jet-[illegible] drags along with it by


frictional contact a very considerable volume of air, which, on reaching the bottom of the bottle S, separates from the water and passes to the blow-pipe through the rubber tube before named, the water finding an exit through the discharge syphon S.

Now let us see how the action of the "trompe" and the apparatus just described is concerned in the casting of an ingot of steel.

Let the beaker *B* (Fig. 7) represent an ingot mould, and the descending stream of water *W* the stream of liquid steel:—it will be seen that the stream *W* carries with it a large volume of air into the water (for illustrative purposes regarded as liquid [illegible] its endeavors to escape, turns, and in the form of [illegible] takes an upward direction parallel with the sides of the beaker (representing the ingot mould). On the stoppage of the stream, all this air immediately escapes from the water, leaving it as homogeneous as water usually is; but, if during the filling of the beaker the water therein was rapidly frozen (the progress of the congelation being from the sides towards the centre), it is evident that the ascending bubbles of air would be entangled in the ice as it formed, and we should have as a final result a vesicular mass or ingot of ice, quite similar as regards its method of formation to the ordinary ingot of steel.




[illegible] illustration may make the formation of vesicles in steel

ingots still more clear. If in place of water in the preceding experiment we substitute mucilage, or any other fluid of similar consistency, we approach much nearer to the actual conditions which exist in the casting of a steel ingot; for the steel as ordinarily melted is never as fluid as water, but approximates more nearly in mobility to the character of mucilage. As, then, the stream of mucilage descends, it will be observed that it carries with it air in the same manner as the stream of water; but that owing to the viscosity of the fluid, the air bubbles rise through it more slowly and escape with greater difficulty, and that some of them, as they approach the surface, are again dragged down by the central descending current. Hence there is a much larger collection of bubbles of air in the mucilage than there was in the water, and, consequently, if the mucilage was solidified at the moment the descending stream was stopped, we should have a much more vesicular mass than in the case of the frozen water in the last experiment.

In comparing the foregoing experimental illustrations with the actual conditions which exist during the casting of an ingot of steel, we find an ingot mould of cast iron (corresponding to the beaker), which is filled by a rapidly descending stream of molten steel (corresponding to the water or mucilage), not as liquid as water, but more nearly of the consistency of mucilage. We also find that this stream carries into the imperfectly fluid mass of steel which rapidly fills the ingot mould a large volume of air, which attempts to rise and escape from the rapidly cooling and solidifying mass of metal in precisely the same way as the bubbles of air endeavored to escape from the water and mucilage in our two illustrative experiments.

But we find another condition present in the case of the molten steel that did not exist in either experiment; viz., the fact of a high temperature in the fluid metal. If we examine this condition, we shall readily discover that it has a very important influence both on the size and number of the vesicles included in the ingot of steel; for it is a well-known fact that dry air, for each 480° F. increment of temperature, increases its bulk by the amount of its original volume. Now, as the fluid steel is at least of the temperature of 3300° F., dry air introduced in the manner illustrated would be so expanded as to occupy seven times the space in the ingot that it did in the atmosphere.

There is, however, yet another fact that tends still further to augment both the size and number of the so-called "blow holes"

that we are considering. It is a well-known practical condition that the air in the immediate vicinity of steel-casting pits is far from being dry. The large quantity of water used for cooling ingot moulds, and for other purposes, keeps the atmosphere surrounding both casting-ladle and ingot-mould in a very moist state, and it is certain that all such vapor-laden air carried into the molten steel would increase in volume for a given increment of temperature very much more than dry air, and would therefore correspondingly increase the size and number of the "blow holes." Furthermore, this vapor of water does not act to this end altogether through its expansion under the influence of heat, for some, if not all of it, is decomposed by the high temperature, and its oxygen, together with that of the accompanying air, is absorbed by the walls of the cavities. This produces the iridescence observed, and leaves in the "blow holes" an atmosphere composed mainly of hydrogen and nitrogen; and it is not at all improbable that in many cases this decomposition of the watery vapor did not take place until the steel was so far solidified as to prevent the walls of the cavities yielding to any great extent, and, under such circumstances, the gases named would be under a very considerable tension.

This view is confirmed by the investigations of Prof. F. C. G. Müller of Brandenburg, who found that the mean composition of the gases in the "blow holes" was

| | | |
|---|---|---|
| Hydrogen, . . . . . . | 79 | per cent. |
| Nitrogen, . . . . . . | 19 | " |
| Carbonic oxide, . . . . | 2 | " |
| | 100 | " |

and that their average pressure was 120 pounds per square inch.

It is of course possible that some of the gases found in the "blow holes" of Bessemer steel ingots may have found lodgment in the steel during the process of "conversion," more especially when steam is admitted with the blast for the purpose of keeping down the temperature of a "hot blow." In this case the steam would certainly be decomposed, and some of the residual hydrogen might remain entangled in the metal; although doubtless much the larger portion owing to its great levity, would escape during the pouring of the steel from the "converter" into the "casting ladle." In the case of open-hearth steel, however, there would be no such reason for the presence of hydrogen.

The foregoing explanation of the presence and methodical arrangement of the cavities or " blow holes " in steel ingots, and the character of the gases found in them, is, I think, sufficient to account for all the facts observed. The assertion which has often been made (as a sufficient explanation), that " the gases are occluded in the steel," deserves to rank with the pompous declaration of a village pedagogue that a total eclipse of the sun which was terrifying his neighbors was " only a phenomenon." " Words of learned length and thundering sound " discourage rather than stimulate the inquiring mind.

I now desire to call your attention to a species of cavity much too frequently found in forgings of steel, that does not originate in the manner already described.

If a large cold ingot is put into a too highly heated furnace, its exterior surface will expand so much faster than the parts at or near its axis, as to strain the metal in the interior of the ingot beyond its elastic limit, and oftentimes actually rupture its central continuity, as is shown at *A*, Fig. 8. Such a breach may in some cases have a diameter equal to half that of the ingot.

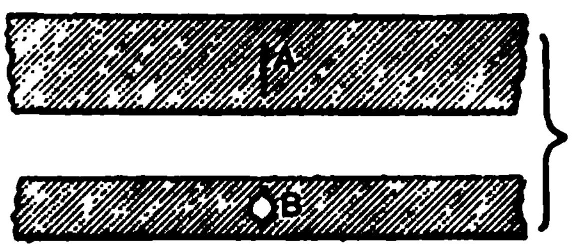



FIG. 8.

An ingot thus internally fractured, if hammered or rolled down to a smaller section, will have a cavity developed in the centre of its mass, as shown at *B*; and unless the existence of this cavity is discovered, serious difficulty may result from the use of such a forging as a part of any mechanism. It is not at all impossible for a number of such cavities to be formed in the same ingot, if the heating be sufficiently rapid, in which case the initial rupture would occur at *A*, Fig. 9, at or near the centre of the ingot; a second and third fracture would


FIG. 9.

then take place almost simultaneously at *B*,*B*, about half way between *A* and the two ends of the ingot; and, finally, a third set of internal breaks may be formed at the points *C*, *C*, *C*, *C*, thus dividing the ingot into eight nearly equal parts of solid metal. The diameters of the several ruptures would vary in the following order, viz: That at *A* would be the largest, those at *B*, *B*, somewhat less, and those at *C*, *C*, *C*, *C*, least of all. Such an ingot—if the internal ruptures were not too large—might be forged into a propeller shaft and actually

put into a vessel, without the defects being discovered until it was twisted asunder on its first voyage.

Such possibilities of carelessness in the manufacture of heavy forgings of steel as I have described make it highly desirable that some method be devised to detect the presence of such internal ruptures before much time and labor have been expended upon the forging, and also to prove its soundness when completed. About twenty years ago, a plan for this purpose was proposed by Mr. S. M. Saxby, R. N., and some extended experiments to test its practical value were made by direction of the Admiralty; but, although the early investigations were very promising, the method has not become established as one of the acknowledged reliable means of testing forgings of iron or steel.*

It is possible that some method of electrical examination may be found of service in testing the soundness of forgings, and I will venture to suggest the following:—

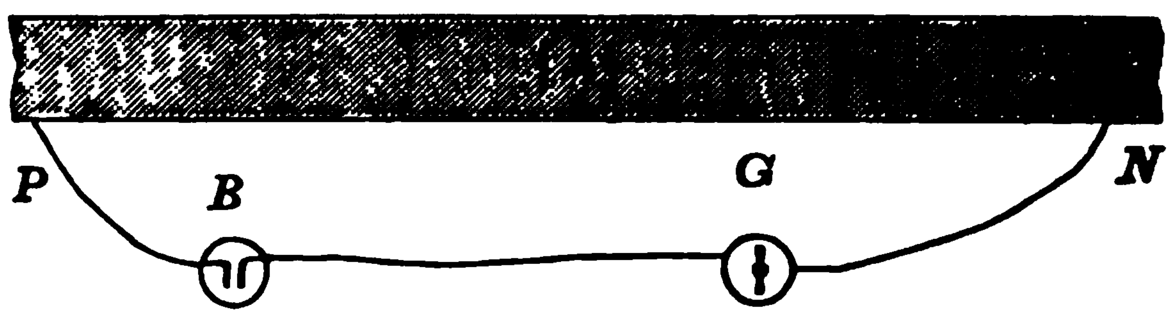



FIG. 10.

Let *A*, Fig. 10, be an internal rupture in the ingot *I*, to the extremities of which are connected the wires *P*, *M*, of the battery *B*, having in the circuit a galvanometer *G*. Under these conditions the galvanometer needle will be deflected a certain amount, which is a function of the strength of the current and the resistance of the circuit; and if by any means the resistance of the circuit is diminished, the deflection of the needle of the galvanometer will be increased. For instance, if, in the proposed apparatus, the wire *N* be moved towards the left, for each inch of movement there will be a corresponding increase of deflection of the needle of the galvanometer; but when the wire passes a point opposite the rupture *A*, the law of the increase of deflection may be found to change, and to indicate the presence of an internal breach of continuity in the ingot or forging under examination. I have had no opportunity to test this method, but make the

* This method is described in an article which was first printed in *The Engineer*, Dec. 7th, 1867, reprinted in *Engineering*, Dec. 13th, 1867, and subsequently embodied in Kohn's Treatise on Iron and Steel, 1869.

suggestion in the hope that some one having the means and leisure will give it a thorough examination, and that it, or some modification of it, may be found of practical value.

Thus far I have spoken only of the transverse internal rupture of steel ingots in consequence of too rapid heating; but longitudinal internal ruptures can be, and often are, produced by the same cause.

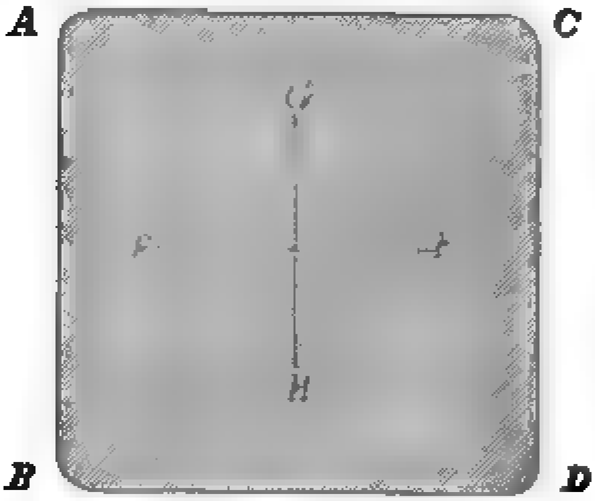


FIG. 11.

In Fig. 11, let *ABCD* represent a cross section of a steel ingot. If too rapidly heated, the opposing sides *AB* and *CD* will expand so much faster than the centre, that an internal rupture *EF* may be formed; and the expansion of the sides *AC* and *BD* may in like manner develop a similar rupture *GH*, located in a plane at or nearly at right angles with that already named.

Such ruptures, though generally situated in planes at or nearly at right angles to each other, are not confined to planes located as shown in Fig. 11, for the planes of rupture may coincide with the diagonal planes of the ingot, or may occupy any position between such diagonal planes and that shown in the figure. In fact, their position is fixed by the resultant action of two forces, due to the expansion of the exterior of the ingot by the sudden heating, modified by the powerful internal strains existing in the cold ingot tending to separate the metal at its centre. These strains were established at the time the metal originally solidified in the ingot mould, and are occasioned by the outside of the ingot cooling, while its interior is either fluid or plastic; and as the whole mass becomes cold, its interior, by the force of cooling contraction, is strained in many cases beyond its limit of elasticity, which limit may with propriety be defined as the beginning of rupture. An ingot of steel thus internally strained would require but the small addition to the tension which a too rapid heating of its outside would furnish, to produce such interior longitudinal fractures as have been described. The extent of the influence of such internal strains in all stages of the manufacture of steel is very irregular and uncertain, and this fact makes them all the more worthy of consideration in all cases in which steel is to be subjected to uses which involve the application of sudden and violent shocks.

Of the effect of such strains in steel used for the construction of cannon, Col. Eardley Maitland, R. A. Assoc. Inst. C. E., Superintendent of the Royal Gun Factory at Woolwich, in a recent paper said: "On a review of the results obtained, the author, having seen so many instances of the fracture of steel, sometimes spontaneous and sometimes under stresses quite inadequate to produce the result, was of the opinion that internal strain was the gun-maker's worst enemy, and that it was a question of great moment whether it was worth while to incur the risk of setting up such strain by oil-hardening."

It is not at all improbable that in many instances (especially in the case of steel having considerable hardness) ingots may be ruptured internally both transversely and longitudinally, thus aggravating the evil of either single species of rupture. If such an ingot were forged into a heavy crank pin, its whole interior would be permeated with most irregular and intricate imperfections, though at the same time the ends and cylindrical surface of the forging might have every appearance of soundness.

As a practical illustration of the great importance of the subject we have been considering, I cannot do better than quote the description of a defective forging given by Professor Thomas Egleston in Transactions American Society of Mechanical Engineers, Vol. VII., p. 263. He says: "I have recently had occasion to examine a forged crank pin made with great care from the best of open-hearth steel. It was rough turned to 16⅜ inches. To ascertain its quality in the centre, an inch and a half hole was bored through it. This hole revealed such a number of cracks and cavities that the hole was increased to four inches, in the hopes of cutting them out. Defects of considerable size were still found. The pin was then sawn in two [planed apart longitudinally], where single horizontal cracks 10 inches in diameter and ¼ inch wide were found, and inclined ones 7½ inches long, in which were cavities ½ an inch wide, to say nothing of defects of minor importance. None of these defects would have been revealed but for the forethought of examining the centre of the piece. If it had been used without this examination, it would have produced great disaster."

I also have had an opportunity of examining the forging described by Professor Egleston, and was told that it was made by one of the oldest and most experienced manufacturers of such work in the country. My experience teaches me that such defective forgings are far more common than the managers of our steel works forges are disposed to admit or even believe.

It is a common opinion that one of the reasons why steel forgings are often found hollow in their interior is the failure to work them under a sufficiently heavy hammer; but no hammer, not even "the hammer of Thor," can do more than aggravate the evil of internal ruptures in ingots of steel.

But let us now turn from this long digression relative to internal ruptures in ingots and forgings, and resume the consideration of the matter of "blow holes" in steel ingots. Having endeavored to explain and illustrate what I regard as the principal cause of the formation of such "blow holes," allow me now to examine some of the consequences of their presence.

The first result of hammering or rolling a vesicular ingot will be nearly to close the "blow holes." I say nearly close advisedly; for although the vesicles may become divided, and be made to change their shape and vary their capacity, even to the extent of becoming microscopically small, they never wholly disappear.

As the "blow holes" are reduced in diameter, the contained gases are therefore subjected to a very great reduction of volume, and consequent increase of pressure in the inverse proportion to such reduction. For instance, if the initial pressure of the gases in the "blow holes" was 120 pounds per square inch (as observed by Professor Müller), and these cavities were, by hammer or rolls, reduced to one-tenth of their original diameter, their capacities would be but one-thousandth as great as at first, and therefore the pressure of the contained gases would be $120 \times 1000 = 120{,}000$ pounds per square inch. But, in estimating the value of this pressure to produce rupture, we must bear in mind that it acts only upon an area one one-hundredth as great as it did originally.

Now let us suppose that an article made from steel in the above described condition is subjected to a heat of 1000° F. (a dull red). In that case, the gases inclosed in the cavities of the steel will, by reason of their tendency to expand, exert three times the pressure that they did when cold, and if such pressure is symmetrically distributed (a not very likely circumstance), the article will when cold retain its original contour; but, if there is more internal pressure upon one side of the object when heated than upon its opposite, distortion will naturally result, a thing not at all uncommon in annealing articles of steel. Thus we see that throughout a bar or other forging made from a vesicular ingot of steel there may exist a vast number of magazines of force, of great though very variable intensity,

but quite sufficient to aid powerfully any external strain which tends to break the bar.

Now let us see what would be the result if the "blow holes" were without gaseous contents. Were it possible to find an ingot whose "blow holes" were absolutely empty, when it was worked, the sides of the holes would come together, but, owing to the low temperature, they would not weld. At the same time, the holes would become elongated and be made to approach each other transversely, and, in fact, would finally develop into "seams" of a variable length and depth, as they chanced to originate from large or small holes. Such a state of affairs, as may be readily understood, could have very little influence upon the ultimate ability of the bar to resist a tensile strain; but, if such a bar were subjected to compression, it is easy to see that it would yield unequally, and much sooner on the side having the greater number of such seams.

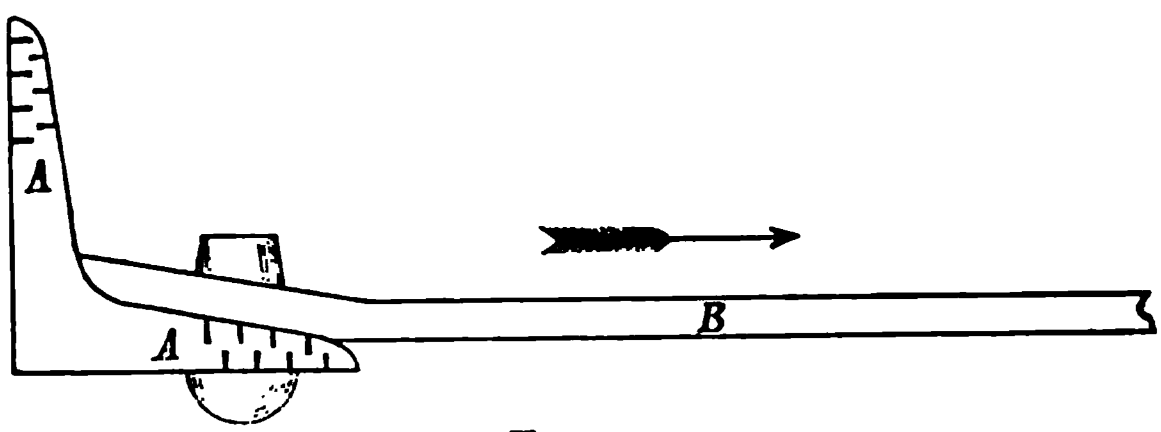



FIG. 12.

But it is when such a bar is subjected to a transverse strain, tending to pull it apart in a direction perpendicular to that in which it has been worked, that these seams are the most injurious. Take, for example, an "angle iron" made from such an ingot: it is not at all improbable that the "seams" would be so arranged in the flanges (as at *A*, *A*, Fig. 12) as nearly to separate them into a series of rods held together transversely by occasional ligatures of metal. Now, if such a bar be punched or drilled through the "seams," and another bar *B* be riveted to it (as shown in the figure) and subjected to a strain in the direction of the arrow, it is self-evident that the "angle bar" would be much more likely to be pulled apart transversely through the rivet-hole than if it were made of a homogeneous material.

I think I have said enough about "blow holes" to convince any one that under the ordinary methods of manufacture they are very likely to occur, and that they are exceedingly objectionable things to

have in the metal; and now let us examine the efficiency of some of the methods that have been devised to mitigate the evil of their presence.

Some years since, the late Sir Joseph Whitworth proposed and practically carried out a mechanical process of compressing steel in the ingot mould while it was still fluid or plastic, his intention being to destroy the "blow holes" by the action of the enormous pressure employed. He certainly succeeded in turning out from his works most admirable products in steel; but I have always had a feeling that the high character of his forgings was due more, much more in fact, to the chemical constitution of the metal, and its having been skillfully heated and carefully worked, than to any qualities resulting from its having been compressed while in a fluid state.

Let us examine this matter a little more closely. Suppose *I*, Fig. 13, to be a vertical section of an ingot mould filled with fluid steel *S*, (having more or less "blow holes" distributed through its mass, as indicated by the small circles,) which may be forcibly acted upon by the plunger *P*. Now, as fluids under pressure act equally in all directions, it is evident that all the "blow holes" will be reduced in size, and also that the tension of their contained gases will be increased in the inverse proportion to their reduction in volume; but it is not so clear that there is any action that will cause their removal from the steel altogether.

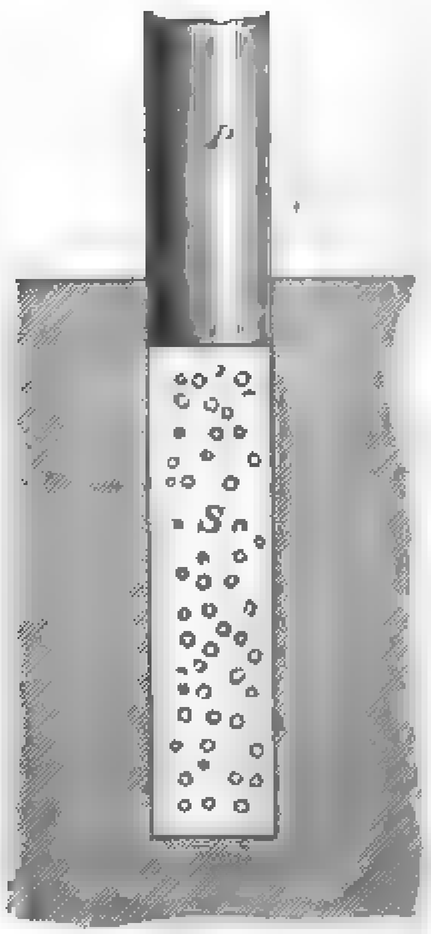


FIG. 13.

The same reasoning applies to all systems of vertical compression, whether by the action of carbonic acid, as employed by Herr Krupp, or by high-pressure steam, as at one time used in this country.

Some system of closing the top of the mould and producing a vacuum above the steel would seem to be a more rational mechanical method of removing the "blow holes," than any system of compression; for, as the pressure upon the steel was reduced, the gases in the "blow holes" would expand, and their augmented levity would cause them to escape from the fluid steel with greater rapidity than is possible under any other condition. But, after all, the simplest

way of getting rid of the "blow holes" in steel is so to treat the metal before it is run into the ingot mould, that its capacity for heat is increased to such a degree that it will remain fluid long enough to permit the gas-filled "blow holes" to escape as freely as bubbles from water.

This suggestion brings me naturally to a consideration of the "Mitis process"; but before entering upon it, I desire to speak briefly of some points relating to the very important practical operation of hardening and tempering steel. As regards the latter process, it would be for the advantage of all who use tools of steel, if the subject could be disposed of in as few words as comprised a somewhat famous account of snakes in Ireland, which simply declared that "there are no snakes in Ireland." I wish it were possible to say that there is no such thing as the present practice of tempering steel; for I am firmly of the opinion that much better results can be attained in its use by simply hardening it at such a temperature as by practice with the particular steel used is found most satisfactory, and omitting altogether the lawless and uncertain operation known among mechanics as "drawing the temper."

I have in my possession an admirable illustration of the possibilities of the methods suggested, in the shape of a razor made from the first Bessemer steel produced in this country. This steel, judged by the ordinary standards for "razor steel," would be considered altogether too soft for the purpose; but, nevertheless, by hardening it as much as possible, and leaving it in that condition, it made so satisfactory a razor that my father shaved himself with it for fifteen years.

I have already referred to the views of Colonel Maitland relative to hardening steel, and feel sure that the practical experience of all who have had the most to do with that operation leads to a similar conclusion.

In this connection it will be instructive to quote some of the remarks made by acknowledged experts during the discussion of a paper communicated to the American Society of Mechanical Engineers by Professor John E. Sweet ("The Unexpected which often Happens"; see Transactions American Society of Mechanical Engineers, Vol. VII., pages 156 to 160). In this discussion, Mr. Henry R. Towne, President Yale & Towne Manf. Co., speaks of numerous unsuccessful attempts to harden certain castings of steel, and states that it was finally discovered "that the steel hardened beautifully *inside*, but that there was on the outside a thin skin of metal,

about three to four hundredths of an inch in thickness, which, except by the cyanide process, did not harden at all. In all of the castings there was perfect hardening under this skin; and finally, the moral of this is that we should *look below the surface*"— a moral, I will add, which should not be forgotten by those who hope to succeed in the employment of steel. In the same discussion, Mr. Geo. M. Bond, Superintendent Gauge Department, Pratt & Whitney Manf. Co., said: "We find in our experience in making taps and reamers, that in case the steel has been over-annealed and has thus been decarbonized, the hardening does not take effect except under the surface, so that frequently, taps which appear to be soft, if turned again will harden perfectly. I think perhaps the castings referred to by Mr. Towne may have been over-annealed, and in that way a percentage of the carbon eliminated so that the hardening would not take effect upon the outside surface." In the same discussion Mr. Bond further remarks: "We had occasion to make a set of gauges in which the sizes were all two ten-thousandths of an inch larger than the nominal sizes, and five days after the gauges were finished, one of them suddenly gave way in the centre, a crack extending around it spirally, but not so as to injure the ends of the gauge. Out of curiosity, I thought that I would measure the uninjured parts to see if any change had come in the diameter, and I found at both ends the diameter had enlarged forty divisions of the micrometer, which is equal to six ten-thousandths of an inch, and which, as magnified, represented a space to the eye of about three-sixteenths of an inch under the microscope. This shows, I think, that if steel hardens at all, the internal strain must be something tremendous. This will also explain why steel, in being hardened through the centre, has a tendency to shorten under certain conditions."

Professor William A. Rogers, Assistant Professor of Astronomy, Harvard University, said: "The unexpected has *always* happened to me in this matter of obtaining hardened steel which has a homogeneous temper throughout the entire mass. The nearest approach to an even temper which I have ever been able to obtain has been at the works of Miller, Metcalf & Co., of Pittsburgh, and of Brown & Sharpe, of Providence. A short time since I asked the latter firm to set a price upon a hollow steel cylinder six inches in diameter, three feet in length, having walls half an inch in thickness, hardened and ground on the outside only. The price which was set—from $300 to $500 without guarantee against flaws—may be taken as the estimate

of the extreme uncertainty always attending any difficult case of tempering held by those who have a full comprehension of the difficulty of the problem.

"The difficulty of giving a homogeneous temper to a large mass of metal is so great, according to my experience, that it is never perfectly done. The test which I apply as the gauge of an even temper is a very severe one. If all the lines ruled upon a highly polished bar of tempered steel have the same appearance, the temper of the graduated surface is good. I have, however, never yet seen a set of graduations in which the diamond has with a constant pressure cut all the lines to the same depth. The diamond acting upon this polished surface detects the lack of homogeneity in the most perfect manner. If there is any person in this country, or in the world for that matter, who can temper a bar of steel three feet in length and for a depth of even a quarter of an inch, at any price, I should be glad to make his acquaintance."

Mr. George Ede, in that chapter of his work on "The Management of Steel" (edition of 1866) descriptive of the method of "toughening of steel in oil," as at that time practised "in the Gun Factories' department of Her Majesty's Royal Arsenal, Woolwich," says, relative to hardening solid steel shot: "Thick lumps of highly carbonized steel, whether hardened in oil or pure water, or water with a film of oil upon its surface, cannot be hardened without becoming fractured either internally or externally." In this matter of hardening steel, the value of the "personal equation" of the workman is all important. It is not uncommon to find a practical mechanic who usually has good success in the use of a certain kind of steel with which his neighbors, equally skillful perhaps in other matters, can do nothing. So often have I encountered this fact, that I am inclined to believe that if a person in pursuit of information as to the proper quality of steel to use for any given article should travel through this land and obtain the honest opinion of all who were making the article in question, that "the last state of that man would be worse than the first"; for the chances are that every person consulted would have an opinion differing from those of his fellow-craftsmen, and although when our traveller started on his search for technical wisdom he was positive that he knew nothing, he could not rejoice in even that negative certainty when he returned. In the present state of our knowledge, there is no recognized uniform scientific method of hardening and tempering steel: all we have is a tentative art, as crude in its development as it is obscure in its origin.

And now let me crave your indulgence for a few words relative to the "Mitis process." The word "mitis" is a Latin adjective, meaning mild, soft, or ductile, and it was selected because of its appropriate signification, as the designation of the new art, by its Swedish inventors.

I regard this process as one of the most important improvements in the metallurgy of iron and steel that has been brought forward during the past twenty years. By its means we can produce castings of melted wrought iron, or of steel of any desired hardness, that, without having been annealed, can be forged, welded, bent cold, or worked by machine tools, with as great facility as ordinary forgings of wrought iron and steel.

From among various samples I have selected two articles which will serve to give a good idea of the possibilities of the new art. One of these is a horse-shoe with "nail holes" and "creases" complete, cast of melted wrought iron in an iron mould—an impossibility by any other process. The other is a beefsteak pounder, in the condition in which it left the "dry composition" mould in which it was cast; this also is made of melted wrought iron. On the extremity of each tooth there is what appears to be a wire. These seeming wires were made by the melted wrought iron filling the "vent holes" of the mould; a thing which I never saw to anything like the extent shown in this sample in the case of castings made of any metal by any other process. In fact, one of the most remarkable attributes of this new art is the extreme fluidity of the metal at the time of casting, and in this fact is one of its greatest technical advantages; for this exceeding fluidity enables all the "blow holes" to escape before the casting or ingot solidifies, thus getting rid of one of the chief obstacles to sound forgings in iron and steel.

This fluidity of the melted metal is produced by the addition of a small percentage (0.05 to 0.1 of one per cent) of the metal aluminium to the melted wrought iron or steel immediately before casting: this addition at once produces a degree of fluidity in the molten metal comparable with that of water.

The reason for this result cannot be explained, but it can perhaps be made more comprehensible by an illustration.

The soft metals—tin, lead, zinc, antimony, bismuth, etc.—melt singly at temperatures varying from 600° to 1000° F., but if a proper selection and combination from these metals be made, we shall obtain an alloy that will melt at the surprisingly low temperature of 170° F.

Under ordinary conditions, melted wrought iron or low steel is pasty or semi-fluid, and it has been found that, without increasing the temperature, the addition of the small percentage of aluminium named acts upon the metal very much as the soft metals in our illustration act upon each other,—it increases the fluidity of the mass, and thus enables results to be attained that have hitherto been impossible. Castings made by this process are, as a rule, ten per cent stronger than the scrap iron melted to produce them ; and in the case of steel there is a like increase of strength without any diminution of elongation previous to rupture, a property which is of great practical value. I regard this process as of great value in the manufacture of material for great guns, as by its use sounder and stronger ingots of steel can be insured from which to forge the component parts of built-up guns; and, furthermore, I believe it quite possible, by the use of this process in connection with the Rodman system of casting, to make a solid cast-steel gun that will be more efficient and a great deal cheaper than any built-up gun can possibly be.

The question of national defense is no trivial one, and before deciding upon the method to be adopted in the manufacture of our future arms, the merits of all systems should be carefully considered. The laudable purpose of our government to provide adequately for the defense of the nation gives to the general subject of the manufacture of heavy guns great interest at this time. That people who would preserve peace must be prepared successfully to defend peace; and a nation so prepared will rarely need to use its weapons.

The industrial victories of peace make possible war's triumphs in the defense of peace. And therefore a nation's first step in its own defense should be to foster the industries of its own people, and cordially encourage those who, with thoughtful brain, willing hand, and ready purse, stand prepared to mine coal and ore, to make furnaces roar and melt with fervent heat, while mighty engines throb and ponderous hammers beat, and, anon, gigantic tools, in whose stalwart frames and cunning fingers are crystallized the brain and brawn of generations of workers in thought and substance, give final shape and proportion to the arms of our defense, that peace and concord, prosperity and happiness, shall be ours while time endures. To this end should all labor tend—

> "Till the war drum throbs no longer, and the battle flags are furled,
> In the Parliament of man, the Federation of the world ;
> When the common sense of most shall keep a fretful realm in awe,
> And the kindly earth shall slumber lapt in universal law."

## DISCUSSION.

Lieutenant R. R. INGERSOLL.—*Mr. Chairman and Gentlemen* :—I have only one objection to offer to what the author has said in his able and instructive paper, and that is as to the possibility of making a modern gun with Mitis iron or steel by the aid of the Rodman process of casting. There is but little doubt that a sufficiently strong gun cannot be produced by the Rodman system of casting, for the simple reason that, however beautiful the theory, it is impossible to realize in practice the state of initial compression of the bore indicated by the theory. This is conclusively shown in the case of cast-iron guns, the process of casting which is very much easier than is the case with steel guns. The elastic limit for compression of cast iron being taken at about 26,000 pounds per square inch, the initial compression at the surface of the bore of the completed gun should equal this amount in order to compete with built-up guns ; but thus far, an initial compression of 12,000 pounds, in the case of the 12-inch cast-iron gun built at South Boston, is about the limit reached. Again, the elastic strength of Mitis iron being, as compared to gun steel, not over two-thirds the latter, the material is not sufficiently strong, especially in view of the fact that the day is not far off when 2500 f. s. and 25 tons pressure per square inch will be as common as 2000 f. s. and 15 tons pressure per square inch are to-day.

I am glad to hear the author take such strong ground as he does in regard to the existence of blow holes in steel castings. It is as strong an argument as can be desired against the practicability of producing sound, strong guns of cast steel by the Rodman process.

The paper is most interesting and instructive, and I regret that the author is not present, because he could, perhaps, clear up many points upon which some of us may possibly be doubtful.

The following reply to Lt. Ingersoll's remarks was received by letter:

MR. DURFEE.—*Mr. Chairman and Gentlemen* :—In reply to the criticism of Lieutenant Ingersoll, I will say that the behavior of melted wrought iron or steel, when treated by the "Mitis Process," is so different from that of these metals not so treated that, in the absence of actual experiment, it is hardly just to assert that this new process is not available for the manufacture of heavy guns by the Rodman system, or some modification thereof; and if a thorough trial should prove its unfitness for use in this way, it could hardly fail to be of great value in ensuring sound ingots from which to forge the parts of built-up guns.

In view of the many failures of built-up guns made by the aid of the best talent and largest experience abroad, I think it the part of a conservative wisdom to hasten slowly enough in this (for our country) new manufacture ; to "prove all things and hold fast that which is good."

On the motion of Commander W. T. Sampson, a vote of thanks was given to the author for his valuable and instructive paper.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

MAY 6, 1887.

COMMANDER P. F. HARRINGTON, U. S. N., in the Chair.

# A NEW METHOD FOR CARRYING AND LOWERING, AND FOR DETACHING BOATS; ALSO A SUGGESTION FOR DEFENDING SHIPS AGAINST AUTO-MOBILE TORPEDOES.

BY LIEUTENANT D. H. MAHAN, U. S. N.

*Mr. Chairman and Gentlemen*:—The models I wish to exhibit to you this evening I have spent a great deal of time and thought upon, but until now I have hesitated about presenting them.

## I.—FOR CARRYING BOATS AT SEA.

My plan, which I hope will elicit the ideas of others, is so to carry boats on board ship that they may all be lowered, either on one side or the other, or on both sides, as the case may require. How to do this I will explain by experiments with my model. First, I have the arms in position to receive the boat as soon as hoisted. Let us hoist the boat to the davit-head. As soon as hoisted, men on the rail turn the cradles under the boat and the guys are set up. The boat is lowered into the cradles and hauled inboard, the falls being unhooked. Carrying the boat across the ship and hooking the other falls, we prepare to lower the boat by running the cradles to the outer ends of the arms and hauling taut the falls. (This is the position of the boat, if at sea and expecting to sight an enemy's fleet.) Two men on the rail unhook the brace bars. As soon as the bars have been lowered, a man stationed on deck, by bearing down on the triggers, immediately removes both cradles from under the boat, and the men on the rail turn the cradles alongside the ship in either direction. The boat can now be lowered.

The arms are raised into place by hooking the boat falls into the hook on the ends of the arms. Since the guys have not been let go, the arms will swing into position as soon as hoisted, and owing to the shape of the joints will catch of themselves. As soon as hoisted, the brace bars are hauled up into place. If it be desired to get a second boat out on the same side:—before hoisting the arms into place, hoist the cradles already on the arms inboard, and then hoist the arms into place and run the second boat out. In case of a ship in danger of foundering, there will be no necessity for hoisting the arms into place, but instead run the second boat out, steadying the cradles by the in and out tackles, and when the falls are taut, ease out and allow the cradle to go overboard.

My idea is to have the boat carriage and cradle made of paper, so as to reduce the weight as much as possible. If it be desired to change cradles, it can readily be done by removing the bolts which secure the cradle to the carriage. The carriages are secured at sea by wedging up, thus raising the rollers from the tracks and at the same time pressing the clamps of the carriage close against the under side of the track.

## DESCRIPTION OF MODEL—PLATE I.

*a*, boat carriage and cradle, made in two parts and bolted together. The cradle depends on the style of boat used. The carriage is a simple oblong box, without a bottom. It has eight rollers inside of it, placed in pairs. There should be a bolt-ring at each end and in the centre of each side, used for tackles. The carriage has a clamp at each corner, passing under the track to prevent the carriage from tilting forward or aft.

*b*, outrigging arm forming a continuation of track. At the outer end there is an upright, *v*, which prevents the cars from running off the track.

*c*, track across ship, T-shaped. This track is supported by stanchions *t*; outboard of the stanchions the lower part of track is cut away to leave room for the wheel which is required to turn the cradles from the boat.

*d*, supporting arms for *b*, moving around a bolt at *f* and at *g*, hinged at *e*.

*e*, hinge.

*f*, bolt.

a movable collar working on *h*, self-adjusting when raising or ng arm *b*.

*h*, upright bar, resting in casting step *i*, passing through casting *k*, and having wheel *n* secured to its upper end.

*i*, casting secured to ship's side.

*k*, casting secured to ship's side.

*m*, support for inner end of arm *b*, having a bolt passing through the sides of *m* and through *b*. This support is secured to *h* just clear of *k*.

*n*, wheel secured to head of *h*, used to revolve that bar.

*o*, on one side shows position of pin on which the brace bar *p* rests; on the other side, how the brace bar is cut to rest on the pin.

*p*, brace bar, intended to prevent the hinge *e* from giving away unless intended. These bars have to be removed before the cradle can be lowered.

*q*, line leading from near hinge *e* to head of lever *s*. This line breaks joints as soon after the brace bars are lowered as desired.

*s*, lever intended to tauten line *q* when breaking joint *e*, thus allowing arm *b* with carriage and cradle to drop from under boat. There are two levers, one to each arm, so placed on a bar running fore and aft that a movement of one causes a corresponding movement of the other.

*t*, stanchions supporting tracks; there are other stanchions in amidships.

*v*, upright at end of track to prevent carriages from running off.

*w*, hook by which arm is hoisted into place again.

This model was conceived some years ago, but I had laid the drawings aside. Two years ago I was reading Commander Hoff's book on "Examples, Conclusions, and Maxims of Modern Naval Tactics," in which he writes as follows:

"Will not the lowering of torpedo boats just previous to an engagement be fraught with danger, by giving the enemy a chance to concentrate and ram you?"

"To get the boats into the water, speed must be reduced."

"Now, if at this stage either fleet attempts to get the torpedo boats into the water, the other fleet would have a great advantage if they bore down upon them at full speed and engaged them."

"Two fleets meeting at night . . . . your torpedo boats cannot be gotten into the water."

"Captain Rivet is of the opinion that no faster speed than 8 or 10 knots will be maintained during an action."

These passages determined me to perfect this model, as I knew

[illegible] detaching a boat while the [illegible] The [illegible] I will describe to you [illegible] the report made upon it by a [illegible]

## [illegible] DETACHING APPARATUS.

[illegible] but as they are only [illegible] encountered by them. [illegible] apparatus is that a hook with its bearing [illegible] the centre of motion is bound to fall [illegible] The hooks are [illegible] across. The controlling [illegible] I wanted one that would not [illegible] pulled out. The first [illegible] operated by interior springs [illegible] by the drawing of the [illegible] to detach the boat. The second [illegible] the inner end of the bolt [illegible] slightly concave. The [illegible] light wire rope passing under [illegible] of the boat and connected one to each [illegible] two handles on the inside of [illegible] Pulling the after handle disconnects [illegible] the forward fall. The boat [illegible] this way. I believe this to be [illegible] one end at a time.

[illegible] a few extracts from the report.

[illegible] apparatus a trial under circumstances as [illegible] actual service on board a sea-going [illegible] the U. S. tug Monterey. [illegible] of San Francisco Bay, where a topping [illegible] pitched and rolled heavily.

[illegible] making about 11 knots, sea a little on [illegible] the boat was lowered with bolts withdrawn. [illegible] the water freed herself from the tackles. [illegible] made in a sea-way, the boat swung [illegible] of guys, and span upon the davits, was [illegible] by the unhooking of the forward fall, [illegible] water trials.

[illegible] water the boat was lowered a number of times, both [illegible] going at full speed, in all of which cases she cleared

herself successfully. In all these cases the bolts or keys were withdrawn before lowering.

"The trial was then continued with the bolts or keys in place, properly attended and withdrawn at the word of command, after the boat was water-borne, with the same success as before.

"It is evident that the invention has several advantages, such as simplicity, cheapness, strength, non-liability of getting out of order or of being in any way obstructed by passengers, freight or boat equipment, facility with which the boat clears herself from the tackle when water-borne, and great ease in hooking on for hoisting in a sea-way.

"The principal disadvantages appear to be the necessity of lowering the boat square, or a little by the stern, and a careful attendance of the bolts so that they may be instantly withdrawn upon the boat striking the water, a difficult matter in moments of haste or excitement."

Now, the first of these disadvantages is common to all boats, as no one would lower a boat bow first with a ship moving ahead; the second appears no longer to be a disadvantage when the necessity of knowing the boat to be safe in the water before letting her go from the falls is considered.

Seamen differ as to when the boat should be let go, and some have said to me that my apparatus would be excellent were one able to detach the boat in mid-air. To afford no ground for such a complaint, I have had fitted to this boat an arrangement by which the boat can be detached in mid-air, and in putting it into the boat it is so arranged that the stern will start an instant before the bow, thus doing away with the necessity for lowering the boat square or a little by the stern. This mid-air arrangement can be taken out when in port, as there is then no necessity for its use. The hole for the mast is used, and the step for this little windlass can be used as a step for the mast.

With this addition to my detaching apparatus, I claim that a boat can be detached in any way and at any time that may be desired, and, moreover, with perfect security against accidental detachment. I can detach either end first, or both at the same time; either in the water or in the air; with the ship lying dead in the water or going at full speed; and with the boat loaded or empty. Everything connected with the apparatus is above the line of thwarts and all parts are easy of access. Then, again, you can get into the boat and play with the apparatus and it will not go off. If, while a boat was being lowered with bolts withdrawn, a sea should strike near the bows, both ends would unhook. If this should not happen—if the bow

only unhooked—upon letting go the after fall, the boat would free herself.

The following experiments have been tried successfully:

1. Disconnecting both ends when water-borne, no one in boat.

2. Disconnecting bow when water-borne, no one in boat.

3. Disconnecting stern when water-borne, no one in the boat.

4. Disconnecting both ends when in the water, a man attending the bolts.

5. Disconnecting bow when in the water, a man attending the bolts.

6. Disconnecting stern when in the water, a man attending the bolts.

7. Disconnecting in mid-air, both ends.

8. Disconnecting in mid-air to show that the stern starts first.

9. Stepping on bolt lines to show that bolts will only draw by a direct pull.

10. Swinging boat with bolts drawn to show that the apparatus will not detach by any motion of boat.

## Description of Model—Plate II.

Fig. I. Shape of boxes as used in bow and stern.

Fig. II. Shape of boxes when placed more towards the centre of boat.

*a*, ring attached to lower block of boat fall.

*b*, hook,—its shape shows why it falls if uncontrolled.

*c*, hole for controlling bolt.

*d*, hole for bolt around which hook revolves.

*e*, hole for use in towing, being towed, or by means of which the boat could be suspended if desiring to overhaul detaching apparatus.

*f*, holes for riveted bolts.

Fig. III. Shows three views of controlling bolt.

1, bolt showing detent open, and flare of bolt.

2, bolt showing hollow for detent, slot in detent, shape of detent, and springs out.

3, same as 2, but with springs compressed.

*m*, head of bolt, showing hole where the line is fastened.

The mid-air detachment consists of a very small windlass placed thwart, fitting through the mast hole and into its step. led from the windlass, one to the forward hook, the er hook, and fastened to the holes in the heads of the

hooks marked $x$. The after line is of such a length as to tauten an instant before the forward line. As long as the bolts are in the boat cannot be detached,—but withdraw the bolts, ship the lever and heave on the windlass, and a motion through an arc of 20° will detach the stern; through 30°, the bow.

## III.—Proposed Defense against Auto-mobile Torpedoes.

In proposing this protection I would like to say that other protection would be necessary against large torpedo boats, this one merely protecting the ship from auto-mobile torpedoes. The combination of two spars, one for the head and the other for the foot of the netting, will keep the netting in place even while going ahead. The nettings are continuous, from well ahead to well astern on each side, and are made in sections of from twenty-five to thirty-five feet. The spars are fitted with guys forward and aft; with distance chains, so that they cannot fall farther than intended; and with chain running from one spar to the other, which facilitates rigging in and out. To the ends of the upper spars are secured the boat falls, or a runner with fall inboard, if in way of gun, the hauling part leading to steam winches on upper deck. To the outer end of each of the lower spars leads a single line, passing through a block at davit's head, and used for easing out the lower spar until the chain between the two spars is taut, and also, if desired, for hauling the lower spar close alongside when hoisted sufficiently by the falls.

Suppose now that the nettings were down and it was desired to get under way. Start all the steam winches, and in five minutes the nets would be clear of the water, the upper spar would be perpendicular, and the lower spar so much raised that the net would be nearly horizontal and above the guns. If not clear enough, rig in the lower spars, allowing the netting to bag between the two spars and lie close alongside the ship. Lowering the netting on either side, in case a torpedo should be observed approaching, can be easily accomplished, and will retard the speed but little. The spar castings *a* are the only stationary parts; the spars themselves can either be unshipped or the longer ones be used for awning stanchions.

### Description of Model—Plate III.

*AB*, water line.

*a*, castings for netting spars.

*b*, castings for heel of davits.

*c*, sleeves for davits.

*d*, spars for head of netting.

*e*, spars for foot of netting.

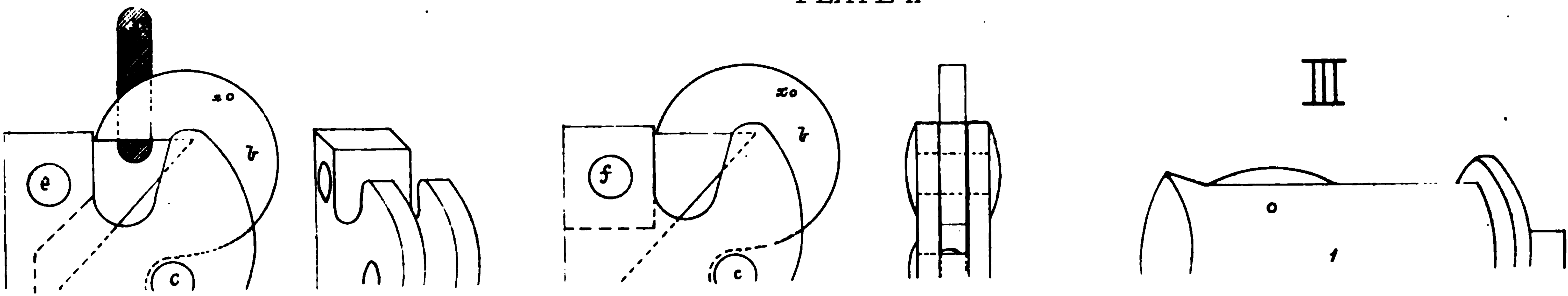
These spars *d* and *e* should be fitted with universal joints. The guys secure half way out. The setting up of the netting from forward guys the outer end of the spars.

*m*, falls leading to winches.

*n*, whip to trice in lower spar.

*o*, heavy thimbles for lashing or hooking sections of netting together.

PLATE II



broken into small pieces, the most of it carried through the air from forty to eighty rods; and a hole was torn in the ground, there mainly tough clay, about one hundred and fifty feet long, forty feet wide, and from ten to twenty feet deep. All the buildings in the immediate vicinity were demolished, while those which stood within reach of the flying stones were more or less riddled. The loss of life was very small considering the extent of the damage, only one person having been killed outright, although several others were severely injured, of whom some have since died.

Such are the primary facts of the explosion itself. An examination of the ground in the vicinity, and of many of the buildings ruined near by, together with others at considerable distance more or less injured, developed certain minor facts that bear upon the general subject of explosions. Especially do they seem to show that such explosions may produce an earth-wave which may do damage at great distances, the undulation of the ground displacing objects, cracking walls, and shattering glass, much like an earthquake in miniature. Sometimes this may possibly prove the source of the principal destruction.

Looking directly at the destruction itself, the results of the explosion appeared as follows: The buildings nearest the wrecked magazine were all crushed together, and, so far as could be determined from the ruins themselves, were pushed away bodily from the demolished building for a short distance, not more than one or two feet. This shows that the explosives instantly produced a very large volume of gas, which forced itself against the surrounding air and condensed it very quickly, until it gave way in the direction of the least resistance, which would necessarily be upward. This condition was confined to a small circle; for, while such a condensation would produce a wave of air, the mass bodily displaced must be confined within comparatively narrow limits. Displacement would not appear beyond.

Fortunately, at Brighton, no other magazine stood within this area, so that the dynamite in the others was unaffected by the shock, while the rain prevented the fire from spreading by means of dry powder. Outside of this area there was a narrow ring or circular strip of ground, with a radius of not far from fifteen rods, where comparatively little injury was done. One or two magazines stood in this region, and they escaped almost without injury, only being slightly battered by flying stones. Here the air was not moved as a

mass either way. The changes of density to which it was subjected were of the nature of molecular movements rather than motion of any great mass of air. Beyond that area the movement of the air was toward the point of explosion. This was shown by the forcing of the glass outward in all of the more distant buildings, while the walls of at least one dwelling-house and of several of the magazines left standing were thrown down toward the wrecked magazine. Furthermore, the roof of one magazine was clearly lifted and allowed to drop, besides being riddled with stones. These phenomena pointed clearly to diminished pressure of the external air, produced by the explosion, as is noticed in a small way when any gun is fired. Since most of the magazines stood in this region, no blow was struck upon them, and there was nothing to explode the dynamite stored within, else the first explosion would have been followed by others in a series and the damage multiplied.

These phenomena, taken together, seem to indicate the following as the steps by which the destruction was produced, though they followed so quickly that only delicate instruments would have distinguished them: First, the lightning exploded some of the black powder. The blow produced by this explosion detonated (?) the dynamite, tearing up the ground to make the hole, and breaking the foundation stone into small pieces. Then the rest of the powder exploded, sending the fragments away in all directions.

It is very strange that, when the danger from lightning is so well known—one of the same group of magazines was exploded by lightning in 1880—no precautions are taken by the owners for protection. The magazines are low structures, some of them roofed with slate, others with thin metal, in all cases very light, that they may offer but little resistance in case of explosion. The total neglect of precautions against lightning indicates a disregard of the known laws of electricity, or else the mistaken notion that a lightning rod, by furnishing a good conductor, attracts the lightning, and thereby increases the danger in place of being a safe path for the current. When such buildings stand upon level ground, in open areas, they necessarily become the path of any descending flash. If the electricity goes through the building, it becomes a source of danger, because it is likely to meet sufficient resistance to raise the temperature above the igniting point of powder, and it must be carried completely around the powder to insure safety. A network of metal rods carried over the tops of those whose roofs are slated, and given a sufficient ground connection, would

be a complete protection; it would carry away all the electricity, usually silently. To protect those with metal roofs, nothing more would be required than wide strips of metal from the roof itself to the ground. Of course, in either case, great care must be taken to prevent scattering powder on the ground within reach of electricity as it leaves the conductors. The problem of protection in this case has sometimes been compared with that of the protection of tanks in which petroleum is stored. This is a complete misconception. Protection of powder magazines simply requires a proper conductor to carry off the electricity, silently if possible, but so completely as to allow no escape in case of a flash. There are no complicating conditions, such as petroleum tanks present. Nothing, either in the material itself or in the air around, makes that a better conductor than neighboring objects. But in the case of petroleum tanks, gases are constantly rising from the petroleum and escaping into the air around, and particularly directly above. They frequently rise many feet above the tank, and experience proves that the gas, or the mixture of air and gas, is a much better conductor than the air itself. So the tank is likely to become the path chosen by every descending flash, and the problem of protection is not simply to furnish a conductor from the top of the tank, but one that shall conduct the electricity from the top of the ascending gas, always an uncertain height. So far no plan has proved completely successful.

The phenomena show clearly that two sources of danger arising from such terrific explosions must be guarded against. The glass broken within the first two miles proved a rush of air toward the destroyed magazine. The sudden uprush of gas, the mass being very highly heated, caused a vacuum, and the subsequent cooling added to the effect. The air rushed toward the vacuum from all directions, and when it was contained in a confined space, as a closed room, it quickly broke the glass, shattering it into small fragments, which fell outward. But the force which did this work was spent within a comparatively narrow area. Beyond that it only appeared as the back-and-forward movement of an ordinary sound-wave. The distance to which this was carried could not be determined, because beyond some seven or eight miles the report was not distinguished from the ordinary roll of the thunder.

This explosion produced an earth-wave as well as an air-wave. The force of the dynamite, exerted largely downward (?), not only [illegible] the ground out to make a hole, but forced it away sidewise in all

directions. This formed a ridge around the hole, and at the same time it produced a wave, that is, an up-and-down movement of the earth. One observer, who was sitting quietly in a chair about six miles from the magazine at the time of the explosion, described the sensation which he felt as a quick movement down and up again. He was not quite positive which preceded, the motion upward or downward, but he thought that downward. That would indicate that the upward motion of the earth was first, since the human body has the sensation of moving in the opposite direction to the motion of the wave, and that agrees with the appearance of the hole. This earth-wave made dishes rattle in all places where it was felt perceptibly. In the central part of Chicago many plate-glass windows were cracked. These were injured by the earth-wave, not by the air-wave. They were simply shattered from the motion of the surrounding walls, but were not forced either inward or outward. One observer stated that a pane of glass near him was cracked at the moment when he felt the shock, not when he heard the report, which was a little later. This showed that the earth-wave moved faster than the air-wave which produced the sound. There is also reason to believe that this earth-wave travelled much farther than the air-wave. A self-recording barometer in the laboratory of Lake Forest University, about thirty miles distant from Brighton village, showed a sudden movement of the mercury at about that time, which could be accounted for only by referring it to the wave of the explosion. Probably this was not the limit of the movement. Unfortunately, there was no means of determining the rate at which this earth-wave moved. All these conditions combine to surround this remarkable explosion with peculiar interest.

The *Boston Herald* of June 6, 1887, gives an account of a new projectile, known as the Fannon-Winslow shell, which has been perfected by Massachusetts inventors. The idea of the inventor is to place three bottles containing the components of nitroglycerine in the interior of the shell, so arranged that they will crush and their contents mix when the shell strikes any object. Very powerful results are said to have been produced with this projectile.

A report of the trial of the Winslow shell by a board of ordnance officers will be found in the *Report of the Chief of Ordnance U. S. A., Appendix* 15, pp. 103–104, 1885. They describe the projectile as

being formed, like a Butler shell, with an appendage resembling a cascabel. The neck of the appendage, to which a wrench is fitted, is hexagonal. The part corresponding to the knob is a cylinder terminating in a spherical segment. The projectile is divided into two sections. The anterior part is a cylinder with an ogival head, and contains a cavity in which the ingredients to produce an explosive compound are contained. This section terminates at the rear end in a screwed tenon, by means of which it is fastened to the rear section. The rear section is provided with a cavity intended to receive a cast-iron plunger and a charge of rifle powder. Near the base of the projectile is a circumferential groove in which time-fuse composition is driven. This groove is connected with the rifle powder in rear of the plunger. An axial chamber is bored in the plunger and contains a small charge of rifle powder. The rear of this chamber is closed by a screw-plug, containing a vent filled with slow-burning composition.

The materials used for producing an explosive compound are glycerine and concentrated nitric and sulphuric acids. One pint of sulphuric acid and three quarts of glycerine were mixed in one vessel, and three pints of sulphuric acid and two quarts of nitric acid were mixed in another. A portion of the first mixture was placed in a glass jar, while a small jar placed within the first was filled with a portion of the second mixture. The liquid contents of the inner jar and of the outer jar when the inner one is inserted are equal in quantity, hence the proportions of the liquids are: sulphuric acid 2, nitric acid 2, and glycerine 1. The usual proportions, when nitroglycerine is manufactured by the ordinary processes, are about as follows: sulphuric acid 6, nitric acid 3, glycerine 1.

The jars are fastened together by screw-caps, and are placed within a tin cylinder, open at both ends, which fits the shell cavity. Stout cross-bars traverse the open end of the cylinder, and the exterior glass vessel is fastened to the bars by strong bands, which, aided by rubber straps, are designed to prevent the rupture of the jar when the piece is fired. The rupture is intended to be effected in the following manner: The time-fuse is cut at any point, and when the projectile has traversed a certain portion of its trajectory, the charge of rifle powder in the rear of the plunger is fired and the plunger is forced violently forward. This breaks the bottles, and, in connection with the rotation of the shell and the broken fragments, causes an intimate mixture of the glycerine and the acids, resulting in the form-

ation of an explosive compound. When the projectile strikes a resisting object, the shock of impact should (according to the report) cause the explosion of the compound thus formed, or, if this does not occur, then the charge contained in the axial chamber of the plunger will bring about the explosion.

The trial commenced April 23, 1885, when a shell was fired over water from an 8-inch muzzle-loading rifle with 35 pounds of powder. It could not be ascertained whether or not an explosion had taken place, for from the fragments that struck near the gun it appeared probable that the projectile had been broken up by the shock of the discharge. A second round was fired over land with 30 pounds of powder, the fuse being set at five seconds. The shell burst in the air in two and one-half seconds, and from the peculiar appearance of the smoke the rupture was regarded as due to the explosion of a substitution (?) compound. In the third round, fired with a 30-pound charge, over water, no explosion took place. The fourth projectile was exploded by means of an electric primer in an inclosure. The shell broke at the screw-thread into two pieces, the head being thrown some 25 feet out of the inclosure. The bottom was forced against the side of the inclosure.

In conclusion the board report that the acids can be safely transported to any point, the mixture can be effected without danger, and a shell arranged to contain them may be fired from a gun without injury to it. With the mixture used an explosive compound is probably formed, although the proportions of the ingredients used were not such as to give the best results. If they had been, and if the greatest possible amount of nitroglycerine producible by the ingredients which the shell cavity could contain were formed, it is not thought that the effect would be equal to that resulting with an ordinary bursting charge of gunpowder. The board therefore recommend that no further trials be carried on with this device or with devices closely resembling it in principle.

This same volume of the Reports of the Chief of Ordnance contains, on pages 57–59, a report of the tests of the 6-inch shells on the Snyder system* charged with dynamite. The board conclude that it is impracticable to fire shells containing commercial dynamite from a smooth-bore gun when a suitable powder charge is used under this

* Proc. Nav. Inst. **12**, 617; 1886.

system, and although previous experiments by the board have indicated that explosive gelatin can be successfully fired from an 8-inch rifle with a charge of 40 pounds of powder,* and therefore could be safely employed in this case instead of commercial dynamite, yet they do not consider that any trial with it in this system would be of any value, because the projectile employed possesses little penetrative power, and, furthermore, the system is very complicated and expensive. The board does not recommend further experiments with it, since simpler and less costly methods promise greater and more valuable results.

On pages 79–80 of the above report is a description of "M. L. S. Buckner's Aerial Drop for Explosives," which is a method of using high explosives from balloons. The board state that the machine is ingenious, and there seems to be no doubt that it will work and drop its explosives at the fixed time to which the alarm-clock may be set. The machine has to be suspended from a balloon, and to be efficient would require a very accurate knowledge of the force and direction of the wind at different elevations, and, of course, at best could only be used under the most favorable circumstances, and when the wind was blowing in the direction of the object to be reached.

The *Army and Navy Register*, June 11, 1887, p. 380, states that Lieutenant J. W. Graydon (late U. S. N.) has devoted his attention to explosives, and has undertaken—

1. To charge ordinary shells with dynamite in such a way as to render it safe to fire such projectiles from heavy guns with service charges of powder.

2. To use dynamite and powder together in the charge, thereby obtaining an increased velocity without a corresponding increase of pressure in the chamber of the gun.

3. To produce a new explosive which shall be safer while at the same time very much more powerful than ordinary dynamite.

Last winter experiments were made at St. Petersburg with the shell filled with dynamite, and the projecting charges consisting of dynamite mixed with black powder. Four charges of the mixture of thirty-seven pounds each were fired from a 6-inch gun, Navy pattern, the shells containing 102 pounds of dynamite. The velocity was

* Report of 1884, Appendix 17.

1993 and the pressure 1736. Four service charges of thirty-eight pounds of powder, with 102 pounds of powder in the shell, gave a velocity of 1499 and pressure of 1724.

Graydon's method of charging shells was tested by a board of army officers at Presidio, Cal., in 1886. They reported, August 13: "We have witnessed the results of fifty-two shells filled with commercial dynamite fired with the service charge of powder from the 4½-inch siege gun, and they were all fired with perfect safety to the gun, with the exception of two, the results of which were lost on account of the fog. Every shell that struck the bank or cliff fired at (range 2200 yards) exploded by concussion, no fuse being required for the explosion. It is the opinion of the board that Mr. J. W. Graydon has solved the problem of firing shells with dynamite with perfect safety to the gun, and at the same time making explosion sure upon the impact of the projectile; and, pending a full and extended report upon the experiments, the board unanimously recommend that experiments be continued with the 8-inch rifle converted and the 15-inch smooth-bore."

Experiments on this method are to be made at Sandy Hook with the 100-pounder Parrott and 7-inch wrought-iron guns.

The *Revue d'Artillerie*, **30**, 530–538; 1887, reprints from the *Militaire Spectator** *of Breda* an article on "The Use, in Germany, of Gun-Cotton for Charging Projectiles."

In 1883 Messrs. Von Förster and Wolff took out two patents—one for a process for preserving gun-cotton,† the other for the construction of a shell charged with this explosive. The process of preservation invented by Von Förster consists in plunging the gun-cotton, wet or dry, into ether for 15 to 20 seconds; there is formed on the surface a very thin, hard layer impermeable to water and of a yellowish-brown color, thus giving the gun-cotton the appearance of wood. Nitro-benzene or other liquid solvents of gun-cotton may be employed in place of the ether. This layer does not affect the explosive properties of the substance, but diminishes loss by flaking and cleavage, retards decomposition, maintains the humidity at nearly the desired point, and prevents the penetration of paraffine. However, this pellicle contains always some very small interstices through which

* Nos. 11 and 12, 1886, and Nos. 1 and 2, 1887.

† For a fuller account see Proc. Nav. Inst. **12**, 563–602; 1886.

moisture may escape eventually, but this imperfection may be neglected if the gun-cotton is properly stored. Gun-cotton, not coated and containing 25 per cent of water, loses all its water in a few days if it be exposed in a brisk current of air, while the coated gun-cotton, exposed under the same circumstances, is not reduced to the dry state in as many weeks. Besides, the layer is so thin that its combustibility does not constitute a source of danger. In the case of dry gun-cotton for use as primers, after the treatment with ether, the detonator canal is plugged with paper and the disk is dipped in melted paraffine. This forms a second impermeable varnish.

The projectile described by the second patent is of cast iron formed of two parts which screw together, the interior being filled with disks of compressed gun-cotton. At the base of the shell is a fuse which fits into the perforations in the disks. The shell is provided with an ordinary percussion fuse, and this is connected with the primer by a fuse composition, which may be either gun-cotton in fine grains or a mixture of this body with meal powder, or some other nitro compound in fine grains, either alone or mixed with meal powder. The patent does not state how the fuse is held in place.

The arrangements described have been chosen as the result of experiments made at Walsrode on the effect of the explosion of gun-cotton in free air. These experiments of M. von Förster's led to the following conclusions: the power of gun-cotton increases with the density; in the moist state it is more *brisant* than when dry; it is advantageous to produce the inflammation of the charge at the part furthest removed from the object to be destroyed; and, finally, a cavity so placed as to follow the axis of the charge favors its action.

It does not appear that the shell described above has been experimented with, and later experiments on the explosion of gun-cotton in free air do not appear to confirm the conclusions reached relative to the position of the fuse and the existence of the central canal. They have, however, sought to utilize existing projectiles by devising means for charging them through the eye of the shell. These efforts have led to the taking out of another patent in May, 1885, for a method of charging and for a special mode of fixing the detonator.

The gun-cotton is used in the form of prismatic grains obtained by breaking up the compressed disks. They place 200 grams of dry gun-cotton upon the charge of wet gun-cotton. When the charge is in place they introduce a mandril through the eye of the shell, thus forming a canal in the cotton for the detonator and fuse, and they pour

into this space melted paraffine having a temperature of 75° to 80° C. This paraffine fills all the interstices between the grains, and in solidifying binds them into one compact mass. The fuse is similar to the German percussion fuse, model of 1873. The plug is elongated and opened at its lower end; it encloses a capsule containing one gram of fulminating mercury, and is surrounded by a band and tube, both of caoutchouc. The whole arrangement is held in place by a screw. If they wish to obtain a retarded effect they use a longer plug and interpose a fuse composition between the exploder and the detonator. In order to assure intimate contact between the fulminate and the charge they place a 10-grm. disk of dry gun-cotton around the detonator, and protect it from the action of shocks by caoutchouc bands.

The shells are charged before being stored in the magazine, but the detonators and fuses are put in place at the time of firing. A brass tube, destined to receive the detonator, protects the charge up to this time.

In the spring of 1885 the German Government furnished the Walsrode factory with a 15-cm. gun for the trial of this mode of charging. They used lead-covered shells of 2.5 cal. model of 1869, weighing 27 kg. and having a capacity of about 2 dm³. Each shell received a charge of 1.35 kilo. of gun-cotton, with 20 per cent of water in parallelopipedons 10 mm. on the side and 20 mm. long, and 200 grams of dry gun-cotton in cubical grains of 6 mm. on the side. They fired the charge of 1.5 kg. against a parapet situated at a distance of 70 m. The velocity, measured at 30 m. from the muzzle, was 245 m. Out of five projectiles no premature explosion was obtained. Two of them had been fitted with retarded fuses, and these produced deeper craters than the other three. The number of fragments was considerable, and their dimensions did not surpass some millimeters. A shower of fragments were thrown more than 70 m. to the rear.

They exploded a shell buried 1 m. in the earth and obtained a circular crater about 2 m. in diameter, 70 cm. deep, and of a capacity of 1.25 m³.

M. von Förster replaced this method adopted for holding the detonator by another, which is not described, but which seems to have given good results. He pursued these experiments and proved successively all the elements of the proposed system. For this purpose they fired an empty shell furnished with an unprimed fuse,

and with damp gun-cotton in the detonator, and they found that the fulminate in the capsule was not exploded. Then loaded shells containing neither fuse nor capsule were fired. There was no explosion and the gun-cotton was recovered unchanged. Next loaded shells, fused but not primed, were fired with a velocity of 420 m. against a parapet of wood, and afterwards of iron. There was no explosion, but as the resistance was increased the shells were broken up as if empty, and sometimes, though not always, the gun-cotton was set on fire.

Finally, he experimented with shell completely charged, fused and primed. More than 200 projectiles of 8.8 cm. were fired with a velocity of 450 m. The ordinary shells charged with gun-cotton were thrown from the rifled 15-cm. mortar with a velocity of 200 m., and from the 15-cm. gun with a velocity of 400 m. These last two pieces also projected steel shells of 6 calibers charged on the same system. There was no case of breaking up in the gun, and the final explosion was always complete.

In the experiments in breaking up at rest they have counted for a cast-iron 8.8-cm. shell weighing seven kilo., 200 fragments weighing over ten grams each, and 600 weighing from one to ten grams. An 8.8-cm. steel shell weighing 6.64 kilo. gave twenty-three large pieces weighing altogether 2.26 kilo., and 127 small fragments weighing together 2.865 kilo. A cast-iron shell of 15 cm. and 27 kilo. produced 376 pieces of more than ten grams, and 828 pieces of from one to ten grams. It was noticed that fragments weighing less than one gram traversed boards 25 mm. thick.

A projectile of 15 cm. and six cal., containing 9.935 kilo. of gun-cotton, buried vertically in the earth, the bottom being 25 cm. below the soil, produced a crater four meters in diameter and 1.3 meters deep, and having a crater of 7 $m^3$. capacity. An eight kilo. petard gave a crater of 3.5 m. diameter, 1.5 m. deep and 6 $m^3$. capacity; with a charge of sixteen kilo. they obtained a diameter of 5.1 m., depth 1.56 m., capacity 12 $m^3$.

In November, 1885, the *Revista di Artigleria e Genio* announced that the German Government had adopted the Walsrode granulated gun-cotton for charging shells.

In 1882 the German artillery began on their side experiments on the use of gun-cotton for shells. These experiments were made primarily in order to determine the possibility of using large charges in projectiles for the 21-cm. mortar. For this they used cast-steel projectiles with thin walls, and they were five calibers in length.

According to an article in the *Militaire Spectator*, the torpedo shells for the 21-cm. mortar are made in two parts, a body and a head, screwed together. The charge is enclosed in a thin zinc or iron box, and is composed of disks of compressed gun-cotton 5 cm. thick and containing twenty per cent of water. The upper disk carries a cylindrical cavity which holds a primer of dry gun-cotton, and the latter is pierced with a detonator hole. When the charge is placed in the box a rod of wood is inserted in the detonator hole, and melted paraffine is poured in to fill the interstices between the disks. The box is closed with a metal cover pierced with a hole for the detonator. When the box is introduced into the shell the head of the latter is screwed on, and a hollow screw is inserted in the eye of the shell in order to hold the box in place, and at the last moment the fuse and detonator are inserted in the aperture in the screw. The use of disks admits of greater density of loading, the charge being about four times as great as when granulated gun-cotton is used; but, on the other hand, it requires that the projectile should be in two parts, and that special disks should be made for each caliber.

These projectiles have given good satisfaction, not only in the 21-cm. mortar, but also in the 15 cm. and the 28 cm. In the latter piece the shell is loaded with fifty kilo. (220 pounds) of gun-cotton.

The article is accompanied by valuable drawings, which cannot be reproduced here.

From the *Report of H. M. Inspectors of Explosives*, 1886, we draw the following account of two accidents which occurred in the manufacture of gun-cotton. In one of these cases an engine-fitter was heating a piece of cast iron which had originally formed the plunger of a hydraulic press, when an explosion occurred. The iron piston had a hole three-eighth inch diameter down the centre to within one-half inch of the face, when the hole narrowed to one-eighth inch, and it appears that a small quantity of unsuspected gun-cotton was present in the upper part of the hole.

The other accident was of a more interesting character. A workman was in the act of removing some gun-cotton from an acid centrifugal machine at Stowmarket, when it fired and burned his face. The accident was believed to have been due either to a drop of perspiration which may have fallen on to the gun-cotton, or more probably to the presence of a small quantity of oil, the oil can having been temporarily deposited on the cover of the machine, where some

of the gun cotton may have come in contact with it. It was found on inquiry that two similar accidents had occurred previously at this factory, but had not been reported (as they should have been); and this led to inquiries being instituted as to the experience of the Government Gun-cotton Factory at Waltham. It appears that such accidents, viz. the "fuming off" of acid gun-cotton in or on removal from the centrifugals, were by no means uncommon, and these have been variously attributed to a drop of perspiration, to condensation of moisture either on the iron of the centrifugal or edge of the pot, or to the gun-cotton being wrung too dry, so to speak, and thereby becoming heated. The correspondence above referred to led to the institution, by the superintendent of the Royal Gunpowder Factory, of a number of experiments.

These experiments show very conclusively (*a*) that the presence of moisture or oil, even in minute quantities, is liable under certain conditions to produce ignition; (*b*) that such liability is sensibly diminished where mineral oils are used; and (*c*) that the liability varies to a very considerable extent with the temperature of the building.

It may be worth while to quote the following passage from a letter from Colonel Noble, Superintendent of Waltham Abbey, dated September 21, 1886, as bearing upon the subject:

"These accidents appear to occur much more frequently in hot than in cold weather. If the temperature of the air gets near 85° in the shade, the gun cotton, after the acid has been wrung out in the machine, is very susceptible to ignition, and if a small drop of oil or a few drops of water get into it at this period it is almost certain to fume off. Instances have been known where the accident has been traced to drops of perspiration from the face of the man employed in emptying the centrifugal. You will see by experiments on the 8th and 13th September, that when the temperature was from 60° to 70° the drops of water failed to ignite, but drops of oil or oil mixed with water never failed. One drop of oil was sufficient. On the 13th, while I was in the house, one of the centrifugals accidentally fumed off, igniting the gun-cotton in the machine next to it. The comparative frequency of these accidents at Waltham Abbey is mainly due to the very defective accommodation, which obliges the centrifugals to be worked in the same house in which the gun-cotton is purified by the boiling process."

"The Utilization of Waste Acids from the Manufacture of Gun-Cotton" is the title of an article by M. E. Allary, in the *Paint, Oil, and Drug Reporter*, **31**, No. 13, p. 9; March 30, 1887.

In the course of an examination of the waste acids from the manufacture of gun-cotton he made a number of experiments with this liquid, with the object of again using the acid for the manufacture.

1. *Simple Distillation.*—The acid used had a density of 58° B., and was filtered through quartz to remove the suspended flakes of gun-cotton which it contained. 100 kilo. gave:

| | | |
|---|---|---|
| 10.077 | kilo. | nitric acid of 50° B. |
| 6.279 | " | " " " 10° B. |
| 82.302 | " | colorless transparent sulphuric acid of 62 per cent. |
| 1.342 | " | loss. |
| 100.000 | | |

If the distillation is continued the 82.302 kilo. sulphuric acid of 62° B. will give 67.5 kilo. sulphuric acid of 66° B. The acids which were recovered in this way were of sufficient strength to be used again in the manufacture of gun-cotton; the nitric acid alone required a slight bleaching. By carefully conducting the distillation an acid of 48° B. can be directly obtained.

2. *Distillation over Saltpeter.*—Starting out on the assumption that, in the ordinary method of preparing nitric acid, the sulphuric acid might be replaced by the waste acids, and that on account of the increase of nitrogen oxides (the average quantity of which had been determined) a stronger acid could be directly obtained, he distilled these waste acids over Chili saltpeter, and obtained at once an acid of 48.45° B., and when the saltpeter was previously dried, even of 49.4° B. In addition to this he obtained an excess of yield, which must be ascribed to nitric acid contained in the waste acids.

An engineer in the Government powder works near Brest, where gun-cotton is manufactured, on obtaining information of these experiments, raised the objection that small quantities of gun-cotton might be present in these waste acids and give rise to explosions. Repeated experiments, made with large quantities of the waste acids, have, however, shown that after decanting and filtering there is no danger in the further treatment of these acids. (*Bull. Soc. Chim.*)

The *Sci. Am.* **56**, 180; March 19, 1887, states that a number of experiments were conducted lately at the works of Messrs. Heenan and

Froude, Manchester, with a new explosive called "Roburite," which is manufactured in Germany, and is about to be introduced into this country for use in blasting operations. The composition and process of manufacture of this explosive are kept secret, but we understand that it consists of two non-explosive and perfectly harmless substances of such a nature that they may be stored or transported without special precautions or restrictions. These two substances may be mixed together when required, and, in combination, become roburite, a yellowish compound, which will bear rough handling with safety. We understand that an intense heat is necessary to explode it. In order to prove this, the explosive was placed, in the experiments in question, between two plates, which were freely rubbed together and hammered; and a small quantity thrown upon a fire was merely consumed, without exploding.

In order to obtain an idea of the explosive effectiveness of roburite, eight ounces of the explosive were placed in the centre of a plate of the very best steel and exploded. This plate was 3 feet square by half an inch thick, and a bulge of about 1 foot diameter and 3½ inches deep was caused by the explosion. Twelve ounces of the explosive were then placed on a cast-iron plate, 6 inches thick, weighing nearly three tons. After the explosion the plate was found to be broken transversely. Unlike dynamite, roburite is said to be in no way affected by varying temperatures, and if duly protected against damp, it may be kept for years in any climate without its efficiency becoming in any way impaired. It is also claimed by the manufacturers that roburite has an explosive force greater than dynamite by at least 25 per cent.

In exploding, roburite does not produce noxious gases, and therefore may be used without intermission, while the poisonous gases given off by dynamite often necessitate the stoppage of work, in some cases for a considerable time. This new explosive is applicable for use in mines and quarries, and for torpedoes and blasting operations generally. (*Industries.*)

Under the title of "Unsuspected Dangers with Frictional Electricity in Blasting," W. E. Irich narrates, in the *Scientific American Supplement*, **23**, 9172; January 1, 1887, an incident which occurred some years ago, and which nearly resulted in a most serious calamity, through want of knowledge regarding the power of induction.

About a week after the commencement of a long series of experi-

ments, several charges of gunpowder, gun-cotton, and dynamite were submerged in a river, about one hundred feet apart, the object being to learn what the effect of each would be when fired under the same conditions. The firing station and the position of the charges in the river were on this occasion totally obscured from each other, and about one mile apart. The cable employed to connect the charges with the firing apparatus consisted of a stranded copper wire well insulated with "Hooper's compound." Two lines were used for firing the charges, and a third or special cable of the same description was laid for communicating between the two points by telegraph. The three cables were laid on grassy land, parallel to but separated from each other by a space of a few inches throughout the greater part of their length. Electricity for firing the charges was obtained from Baron Von Ebner's ebonite-disk frictional machine.

The two ends of the cables at the river were each connected to a charge, while at the firing station one of the ends was carefully sealed and suspended in the centre of the firing room as a precaution and guard against the possibility of its coming in contact with the firing battery or machine. The other end was connected to the electric generator in connection with the charge to be fired first.

Final arrangements having been completed and all made ready, instructions were telegraphed to fire No. 1 charge, which was carefully and correctly done. Scarcely, however, had the firing key been depressed when word was wired from the river "to stop further operations, and leave everything at the firing station in the exact position it then occupied, as two charges had been fired instead of one only, as directed, and that in consequence a boat and a party of men engaged near the charge had most miraculously escaped being blown to pieces." This was declared by the operators at the firing station to be impossible through any action or neglect on their part.

The matter, however, was too serious to be left without a thorough and searching investigation. There was no question as to the second charge having been fired, and a careful examination of the cables between the points immediately after the occurrence failed to show the slightest sign of their having been tampered with. The evidence tended to locate the cause at the firing station, but how or by what means the charge was fired was quite unaccountable to all, and remained a matter of conjecture for several days, as the spare end of the cable had remained securely sealed and suspended, and was at the time of firing many feet away from the electric generator. A

very careful examination and insulation test of the end of this cable in the firing station proved that it had not been injured or tampered with in any way.

Experiments and investigation led eventually to the discovery of the fact that the firing of the second charge was due to induction. To remove all doubt of this, and for the information of all concerned, two half miles of the same description of cable were placed one foot apart throughout their entire length, fuses being connected to the cables at one end to represent the charges, and the wire being then grounded as before. To one of the cables at the firing station the frictional machine was connected, while the other end was carefully sealed and suspended in the same room as before, and at least ten feet away from the generator. The disks of the machine were given twenty revolutions, and the condenser was discharged, when both fuses fired. Other tests were then made, as given in the following table, to discover the greatest distance through which this inductive action would fire a charge, the wires being arranged as described above:

| Distance of cable apart in feet. | No. of revolutions of the disk. | No. of charges fired. | Distance of cable apart in feet. | No. of revolutions of the disk. | No. of charges fired. |
|---|---|---|---|---|---|
| 6 | 20 | 2 | 20 | 30 | 2 |
| 3 | 4 | 2 | 30 | 30 | 2 |
| 3 | 4 | 1 | 40 | 30 | 1 |
| 9 | 20 | 2 | 40 | 30 | 1 |
| 12 | 20 | 2 | 40 | 40 | 1 |
| 15 | 10 | 1 | 40 | 50 | 1 |
| 15 | 20 | 1 | 40 | 50 | 1 |
| 15 | 30 | 2 | 35 | 50 | 1 |
| 20 | 30 | 2 | 30 | 50 | 2 |
| 25 | 30 | 2 | 30 | 50 | 2 |

It would be dangerous on cables running parallel, and within forty or fifty feet of each other, to employ the frictional machine where more than one charge is connected.

It will be seen from the above table that a charge connected with a cable, one end of which was insulated, could be fired by the inductive action of another cable running parallel to and separated from it by a space of thirty feet when one class of electric generator was employed, whereas with a different generator the second fuse was not fired even when the cables were tied or twisted together, as will be shown by the following tests:

The frictional machine was now removed, and tests were made with dynamo machines and voltaic batteries, but in no instance was more than one charge fired, even when the wires were as close together as it was possible to get them, and then it was the one connected in circuit with the machine or battery.

These experiments clearly show that the detonation of the primary charge fired was not the cause of the second one exploding, and that the action was due to induction only. Had it been due to detonation, both charges would have been fired as readily by a dynamo machine or voltaic battery as with the static machine.

This power of induction could be put to good use, particularly in naval warfare, in firing and destroying the enemy's mines. It may also be interesting to note that, with a thirty-cell Grove battery and similar cable to the above, he succeeded in firing through a fault made by stripping off twenty-four inches of the insulation and submerging the bare wires in the sea. With an induction coil he failed to fire through a fault in the insulation only sufficient to expose the conductor to the eye. Wheatstone's magneto-exploder fired the charge through a leak one twenty-fourth of an inch long, but failed through a fault exposing one-eighth inch of the conductor. Siemens dynamo machine fired the charge through a leak exposing a surface of three-tenths inch, but failed to do so with a larger fault. Von Ebner's frictional machine fired through a leak of four and a half inches of bare conductor. It also fired the charge through a perfect break in the conductor. A four-cell Grove battery fired through three-eighth-inch leak, but failed to do so through three-quarters inch.

In connection with this it may be interesting to note that *Nature*, **17**, 50–53; 1877, in an article on "Modern Torpedo Warfare," in reviewing the results of some experiments undertaken in Denmark two or three years before, briefly says: "Another point was also noted. A current of electricity, if it emanates from a powerful frictional electric machine, traversing one of a bundle of wires, will induce a current in the other wires, and thus bring about the explosion of torpedoes other than that which the operator on shore desires to ignite."

We observe that it is not stated in either of these two cases whether or not experiments were made to prove that the insulation between the wires was perfect.

F. Raschig, *Annalen*, **230**, 212–221; 1885, accounts for the discordant results of the analyses of iodide of nitrogen by Gladstone, *Jour. Chem. Soc.* **34**, 1851, Stahlschmidt, *Pogg. Ann.* **119**, 421, and Bunsen, *Annalen*, **84**, 1, by the fact that the precipitate obtained by adding ammonia water to a solution of the iodide is decomposed by washing with water. Sesqui-iodamine, $NH_3,NI_3$ or $NH_2I,NHI_2$, is first precipitated, but it is converted during the process of washing into $NHI_2$ and $NI_3$. The latter compound dissolves in potassium cyanide, forming cyanogen iodide: $NI_3 + 3KCN + 1H_2O = 3CNI + NH_3 + 3KOH$. The iodide of nitrogen prepared from a solution of iodine differs in its properties from the iodide obtained from the action of ammonia on finely divided iodine. The latter compound is much more explosive than the former, as it is capable of exploding when moist. The composition of this substance has not yet been ascertained.

By reference to the *American Chemical Journal*, **1**, 4–9; 1879, it will be found that J. W. Mallet has already gone over the ground which Raschig has been reviewing, that he has pointed out precisely the same source of error in the work of previous investigators, and that he has determined the composition of the amide produced by the action of ammonia on finely divided iodine and which was explosive under water, and he found that when it was produced with great care at a temperature below 0° C., and by the use of the strongest ammonia water and well purified by washing with ether and alcohol, it had a composition corresponding to $NI_3$ or $N_2I_6$, but with weaker ammonia hydrogen was found in the amide.

Mallet proposes to use the higher formula in view of the general fact that the compounds of nitrogen in which this element behaves as a pentad are those in which instability is chiefly observable, and from noticing the proportions in which hydrogen and iodine have been found in these amides it seems fairly probable that the molecules of these explosive compounds contain two pentad atoms.

T. Klobb, in studying "The Compounds of Ammonia with the Metallic Permanganates," *Compt. rend.* **103**, 384; Aug. 1886, finds that a permanganate of silver and ammonia ($Ag_2Mn_2O_8.4NH_3$) may be formed by dissolving one equivalent of potassium permanganate in water at 10° C., saturating with cold ammonium hydroxide, and adding two equivalents of silver nitrate dissolved in ten times its

weight of water. A crystalline precipitate is formed at once which, when washed and dried, has the form of a violet powder, and is but little soluble in cold water, though more soluble in warm. It slowly decomposes on exposure, losing ammonia and leaving a solid residue. Heated brusquely it fuses and is decomposed. It detonates under the blow of a hammer.

The cobaltic dodecammonium permanganate $[Co_2](NH_3)_{12}(Mn_2O_8)_3$ is deposited as a black crystalline powder when concentrated solutions of one equivalent of luteocobaltic chloride and three equivalents of potassium permanganate are mixed. When dissolved in boiling water it crystallizes out on cooling in small brilliant black crystals having the form of cubes, octahedra, and modifications of these two. When these crystals are heated or struck they detonate.

As a result of further study of the "Diazo-compounds," P. Griess, *Berich. Berl. Chem. Ges.* **19**, 313–320; 1886, has succeeded in producing a number of triazo and tetrazo compounds. Among these is the metatetrazo benzene platinum chloride having the formula $C_6H_4.N_2(NCl)_2.PtCl_4$. This crystallizes in very small roundish yellow plates, nearly insoluble in cold water and alcohol, but decomposed with evolution of nitrogen when heated with these liquids. The dry salt explodes violently when heated. The gold chloride $C_6H_4.N_2(NCl)_2.2AuCl_3$ is obtained as an explosive precipitate consisting of microscopic yellow needles. These salts resemble the diazo compounds in their reactions.

R. Möhlau, *Berich. Berl. Chem. Ges.* **19**, 280–283; 1886, prepares "Nitrosophenol Hypochlorite" by dissolving 1 gram of nitrosophenol in 500 cc. of water, adding 5 cc. of hydrochloric acid, and then running in a solution of bleaching powder until a distinct odor of hypochlorous acid is observed. It crystallizes in slender yellow needles having the formula of $C_6H_4NO_2Cl$, explodes when quickly heated to about 70°, or when touched with a drop of strong sulphuric or nitric acid, and gives Liebermann's reaction. It reacts energetically with amines and phenols, is resolved into nitrosophenol and hypochlorous acid by alkalies, and when heated with dilute sulphuric acid is decomposed into quinone, hydroxylamine, and hypochlorous acid. Acetophenonoxime also unites with hypochlorous acid.

# U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

MAY 16, 1887.

PROFESSOR N. M. TERRY, PH.D., Head of the Department of Physics and Chemistry, U. S. Naval Academy, in the Chair.

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## ELECTRIC MOTORS.

BY F. J. SPRAGUE (Late Ensign, U.S.N.).

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Commander W. T. SAMPSON, Vice-President, in the chair.—The subject of the paper to be presented to the Institute this evening is "Electric Motors," and the lecturer, Mr. Frank J. Sprague, formerly an officer of the Navy and a graduate from the Naval Academy in 1878.

It is but a short time since Mr. Sprague was a student in this laboratory,* and I recall with much satisfaction the interest he always manifested in the subjects taught in the department of Physics and Chemistry. He was always among the leading men in his class in all branches; it was here that he passed his otherwise leisure hours and often his Saturday afternoons. Although his success in the scientific work which he has adopted as his profession is due to his ability and untiring energy, yet, no doubt, his first taste for it and his first successes in its pursuit were acquired here.

The same may, doubtless, be said of a number of other graduates of the Naval Academy who have already attained places of distinction in the scientific world.

I can imagine that it must be a source of gratification to Mr. Sprague to stand in this lecture hall and instruct those who were once his teachers. Though it is not among the substantial rewards of his success, it is well calculated to satisfy a commendable ambition.

Prof. N. M. Terry, head of department of Physics and Chemistry, will preside during the lecture and discussion.

* The meeting was held in the Lecture Room of the Physical Laboratory, U. S. Naval Academy. —ED. COM.

*Mr. Chairman and Members of the Institute*:—In extending my thanks to you for assembling to hear some remarks on a subject of such new and growing interest as that of electric motors, I feel somewhat at a loss how to proceed, because the subject admits of such a variety of treatment. Feeling thus, I have come to the conclusion that perhaps I had better speak of the subject from the standpoint of my own personal experience and practice. I will try to set forth, at first, some of the simpler laws governing the construction of motors and operation of motors, then touch upon the general question of the transmission of power, and, finally, speak of the present and future development of this work.

If some of the truths seem too familiar, I beg you will bear in mind the absolute necessity of fully understanding their fundamental character, and the importance of always referring to them as a basis, if we would correctly explain the operation of a motor, or forecast its operation with any certainty.

In any part of an electric circuit the expenditure of energy is measured by the product of the current and the extreme difference of potential, or $W = CE$.

If this energy is partly expended in heat and partially recovered in useful work, we have the expression

$$W = w + HJ,$$

where $H$ equals the heat lost per second, and $J$ Joule's equivalent.

But if $R$ equals the resistance of the circuit,

$$HJ = C^2R,$$

and we have $$W = w + C^2R,$$

or $$w = W - C^2R.$$

If an opposing electromotive force $e$ exists, which in the transmission of power is the motor electromotive force, commonly called the counter electromotive force, it is evident that

$$C = \frac{E-e}{R}.$$

Hence $$W = E\left(\frac{E-e}{R}\right).$$

Substituting the values of $C$ and $W$, we have

$$w = E\left(\frac{E-e}{R}\right) - \left(\frac{E-e}{R}\right)^2 R,$$

$$w = \frac{E-e}{R}[E-(E-e)],$$

or $$w = e\,\frac{E-e}{R};$$

and we also have the ratio

$$\frac{w}{W} = \frac{e\left(\frac{E-e}{R}\right)}{E\left(\frac{E-e}{R}\right)} = \frac{e}{E}.$$

*That is, the electrical efficiency of the circuit is the ratio of the motor electromotive force to the generator electromotive force, or of the counter to the initial.*

All the energy which is delivered to the motor is expended in two ways—heat and work. Our object should be to have as little as possible in heat; as much as possible in useful work. The current which goes into the field magnets serves to excite them, but the current thus used in maintaining the lines of force in the field magnets may be expressed simply as waste heat, and is measured by the quotient of the square of the electromotive force by the resistance of the field coils. The current that flows in the armature is expended partly in heat. This is measured by the product of the square of the current and the resistance of the armature; hence the resistance of the armature should be as low as possible. All the rest of the energy of the current is expended in work. This work appears in three forms. One is driving the armature in the magnetic field and forming currents in the body of the armature, and will be greater or less according to the formation of that body. Another expenditure of this work is the overcoming of friction of the armature bearings. The third is useful work.

Two distinct theories have been advanced for the proper construction of motors. The one is advocated by Messrs. Ayrton and Perry, and is to the effect that different general principles should govern the construction of dynamos and motors: that in the former the field moment should greatly predominate over that of the armature, while in motors the moment of the armature should greatly predominate over that of the field.

On the other hand, Professor Rowland, Dr. Hopkinson, Messrs. Mordey and Kapp, and I, hold the opinion that the best apparatus for converting mechanical power into electricity must necessarily be the best apparatus for converting electricity into mechanical power, and that the principles governing the electrical construction of one must be also the best for constructing the other. In short, in motors as well as in dynamos, we should aim to have the most intense

magnetic field possible, and the greatest ratio between the magnetic moment of the field and armature which the construction of the machine will permit. It is true that the great varieties of work demanded of motors make their construction often different from dynamos, but this does not affect the truth of the principle involved. So many practical as well as theoretical reasons exist for this view that I cannot see how any doubt can long exist of its soundness, and the fact exists that the most extensive and numerous developments of the transmission of power are made on these lines. Some of the reasons for adopting this view will appear as I proceed.

A motor when running may be considered as a dynamo machine propelled by a current: it has a field magnet like any other dynamo; it has an armature situated in that field, which, either because of the attraction and repulsion of the lines of force, or of the double attraction and repulsion of the poles which are set up in the armature acting on the poles of the field magnet, is caused to rotate. This armature rotating in the magnetic field has an electromotive force developed in it which is precisely of the same kind as would be developed were the motor driven by a belt instead of by a current. The strength of this electromotive force depends upon the resulting strength of field and the speed of the armature. This electromotive force, which may be termed a *motor* electromotive force, is ordinarily called the counter electromotive force, because it is opposed to that of the line current which is flowing into the motor. The difference between this line electromotive force and that of the motor is termed the effective electromotive force, and determines, in combination with the resistance of the circuit, the strength of current which will flow in the circuit.

As I have stated, the province of the field magnet is to produce lines of force which shall pass through the armature. Since this is the fact, it is apparent that we wish to create as many lines of force as possible in the smallest space, with the least weight of metal and with the least expenditure of energy.

In considering, however, the way in which the lines of force can be created, we must take into account a great many elements. One is the character, mass, shape, and distribution of the iron which is used in the cores of the field magnets and in the pole pieces. Another is the mass, space, and distribution of the wire around the magnets. Not less important is the character of the armature body, the space taken up by the wire, and clearance outside of the wire. This mag-

netizing force is represented by the product of the turns of wire and the number of ampères flowing in these turns—in other words, by the ampère-turns; and it is absolutely immaterial, so far as the magnetic result is concerned in the creation of the lines of force, how this product is made up—that is, whether there are a few turns and a great many ampères, or a great many turns and few ampères. For instance, if it takes ten thousand ampère-turns to magnetize a field magnet to a proper degree, we can magnetize it with one turn of wire and ten thousand ampères, or one ampère and ten thousand turns.

When we consider the economy, however, then we wish to have the greatest number of turns and the least number of ampères. In the case cited, if we used ten thousand ampères and one turn, we would be using ten thousand times the energy to magnetize the field magnets which would be expended were we to use ten thousand turns and one ampère.

That form of iron which gives the least length of wire for one turn is of course the circular, and that is the form which I have adopted in the field magnets of most of my machines. When exciting a field magnet from lines of given difference of potential, the ampère-turns which will flow is dependent upon the cross section of the wire alone, provided the mean length of turn is not changed. In other words, if the field magnet is wound with a certain gauge of wire it does not make any difference, so far as the strength of the field is concerned, whether there be simply one turn of the length of say two feet, or whether there be ten thousand turns each of the length of two feet, because just as we increase the number of turns we increase the resistance and we decrease the current, but we leave the product ampère-turns, which we will call $Z$, the same. Economy, however, as I have said, determines that we shall use the largest number of turns which we can place practically in a given space on our field.

Having, then, determined the magnetizing force, we have next to consider what opposes the creation of the lines of force. In some very beautiful experiments made by Dr. John Hopkinson and published in a communication to the Royal Society of London, some elaborate tables were given, illustrated by a number of curves, which showed the magnetic property of about thirty-five specimens of iron and steel, and the strength of field magnets for different magnetizing forces. It was there shown that the best material for commercial purposes to be used in field magnets was pure wrought iron annealed, because it offered less opposition to the

creation of lines of force than any other material. This had been practically accepted as a fact before the publication of these experiments, but I know of none which are entitled to more consideration. The introduction of manganese, sulphur, silicon, phosphorus, or carbon means very radical changes in the qualities of the iron, more so than has generally been realized.

We may make some analogies between magnetic and electric circuits. The magnetizing force or the ampère-turns may be likened to the electromotive force which urges a current over a circuit. As in an electric circuit the current generated depends upon the resistance of the circuit as well as the electromotive force, so too in the magnetic circuit may we very properly consider that the formation of lines of force actually created depends also upon the resistance of the path. The resistance of this path depends upon not only the cross section of any space over which the lines of force have to pass, whether in the metal or in the air, but also upon the specific resistance per unit cross section of the material over which they pass, this being different for cast or wrought iron, and being very much higher than either for air. It also depends upon the length of the space. We would then suppose that the number of lines of force which are created would be the quotient of the magnetizing force by the resistance; but when we come to magnetize a mass of iron, we find that a totally different element comes into play, and this seems to be a force which we may liken, if you please, to a counter electromotive force in an electric circuit—that is, it is an opposition set up to the formation of lines of force, which increases with the degree of magnetization, and finally reaches such a point that it effectually bars any further increase of this magnetization. In other words, if we plot out, as was first done by Mr. Hopkinson, the characteristic of a field magnet, laying off as ordinates the number of lines of force created, and as abscissae the magnetizing forces, we have a curve which starts almost as a straight line from the origin at an angle to both the axes of $x$ and $y$, but soon begins to curve and finally becomes almost parallel to the axis of $x$, or so lightly inclined to it that it becomes a straight line which would intercept the axis of $x$ at a long distance to the left of the origin. This has been explained by considering the curve to be formed of two components, one expressing the lines of force due to the presence of the iron, and the other additional lines of force set up by the coils around the iron; that the first part of the characteristic curve is formed by the sum of the ordinates of both, and the latter

part of it simply by a slowly increasing ordinate expressing magnetization due to the coils around the iron.

I do not feel prepared here to say whether this theory is right or not. If the iron can be brought up to a certain saturation and not be increased any more, then it seems that the air surrounding the conductor may be brought up to a degree of saturation and no further saturation possible. If this is so, it follows that we would finally reach a point in the characteristic curve of either a mass of iron or coils of wire, or these combined, when it would become tangent to the axis of $x$, and no further increase of magnetization would be possible under any circumstances. Physical conditions, however, prevent our reaching this point, because before we would get to that we would burn the coils off our field magnet because of the great heat developed. It follows that with every different shape of field magnet, quality of iron, and distribution of mass, that an empirical formula must be derived to truly express the conditions of magnetization.

To express a value for the number of lines of force, we must in addition consider the inter-polar space. This is occupied by the mass of iron in the body of the armature, which ought to have at least the cross section of iron that is present in the core pieces of the magnet; and it is further important that the space taken by the coils of wire on the field magnet should be just as small as possible. In other words, the gap or space between the pole faces and the body of iron of the armature should be as short as possible because of the very high specific resistance of air.

Mr. Siebert Kapp, in a very excellent book on the electric transmission of energy, has given some formulas for dynamos and motors of wrought and cast iron, and of different forms. But, as he has pointed out, they apply only to low degrees of magnetization, and of course depend upon the quality of iron used.

Although the quality and dimensions of the iron masses in a motor are important, it will be found in practical experience that the resistance of the gap is a no less important feature, and I will cite an illustration showing the important bearing which it has on the construction of a machine. As I have stated, I differ radically from Messrs. Ayrton and Perry in the theory which should govern the construction of a motor. I have said the field magnet ought to be as intense as possible; that is, the greatest number of lines of force should be created that it is in our power economically to produce. The resistance of the armature should be as low as possible, and the magnetization of the

armature should also be as low relatively to that of the field magnet as possible. Suppose that a machine has wound on its armature four layers of wire, and that it has a further space for clearance equal in depth to the thickness of one of these wires. The total gap then may be said to be $5a$, $a$ being the thickness of one wire. *The magnetic moment of this armature with any given radiation of heat per square inch of surface is fixed, no matter how it may be wound, and no matter what its power.* This magnetic moment is, of course, the product of the ampères by the turns of wire. Suppose, for example, this armature be stripped and then wound with one-half the turns of wire, the wire being of double the cross section of that first used. We will assume that the insulation always bears the same ratio to the cross section. The armature would now have one-fourth the resistance, one-half the number of turns, it would carry double the current, the heat radiated per square inch of surface would be the same, the speed would be doubled, the power would be doubled, but the ampère turns would be a constant; and so on in other proportions. Suppose, on the other hand, that the armature be intended for a certain horse power, and have a certain radiating surface, it would, with a given efficiency, have a certain resistance. With this fixed resistance, the cross section of the wire would be in direct proportion to the number of turns. Instead of using eight turns of a certain cross section, laid four deep, suppose we use four turns, keeping the resistance the same. The cross section of the wire would be one-half. The weight of the wire would be one-fourth. The room occupied by the wire would be one-fourth. The capacity of the machine would be the same. The heat radiated with any given current would be the same. The gap would be reduced in the proportion of 5 to 2, assuming that we leave the same clearance. Since, however, we use a lighter wire, we can use a smaller gap, because, having less weight, the wires will have less centrifugal force and a finer binding wire can be used. We have then this new condition of affairs: the resistance of the armature has remained constant; the heat-radiating surface constant; the capacity of the armature constant; the weight of the copper in the armature has been reduced 75 per cent; the number of turns has been halved; the gap has been reduced 60 per cent. If, now, our field magnet was not nearly saturated, the number of lines of force which appear will be about doubled, because of the reduction of the gap; and since the lines of force have been doubled, the counter electromotive force which is set up by the armature at the same speed will be

the same, although there are only one-half the turns of wire that we had in the first place. The magnetic moment of the armature will be one-half what it was. The strength of the field being doubled, it follows that the ratio between the magnetic moment of the field and of the armature will have been quadrupled. There will be less distortion of the lines of force, there will be less sparking at the commutator brushes, there will be less change of lead at the commutator brushes. In addition to this, we have double the strength of field without increasing the expenditure of energy in the field magnet; in short, we see that one of our main objects should be to make with the most intense magnet field the smallest possible gap, taking care, however, that the increase of lines of force which we desire will be obtained by the proper proportion of the gap and the energy expended in the field magnet coils.

One of the most instructive experiments, showing the value and importance of masses of iron in both the field and armature of a motor, is the following: Arrange the motor with a balanced lever of known length attached to the armature shaft, with accurate means of reading the pull in a direction strictly tangent to the circumference of the circle which would be described by the end of the lever. With fixed strengths of current in the field, vary the current in the armature by any of the ordinary controllable means, and take simultaneous readings of the pull. This will give a curve showing the *characteristic of the armature*, which is just as important as that of the field. Then, with known currents in the armature, vary the current in the field, and likewise note the current and torsion readings. These results will give a saturation curve of the field, and an investigation of the data will give some interesting facts about your machine.

Several years ago Professor Moses G. Farmer suggested that I would find it an interesting investigation to determine a characteristic of the effective strength of field magnets by determining the number of feet per second a conductor one foot long would have to move to develop an electromotive force of one volt at its terminals when moving in the active part of the field. I use this method continually in my investigations, and have deduced for this purpose the following formula for the Siemens form of armature:

$$\varphi = p\frac{b \times l \times d \times t \times r}{2750 \times v},$$

where $b$ = number of blocks in the commutator.
$l$ = length in inches of active part of pole pieces of field.
$d$ = mean diameter in inches of the circle of revolution of a coil.
$t$ = number of laps of wire in one coil.
$r$ = number of revolutions per minute.
$p$ = ratio of circle covered by the pole pieces.
$v$ = total e. m. f.

Motors may be described as belonging to one of three different systems. First, those in which the field magnet is excited by a coil in parallel circuit with the armature; second, those in which the field magnet is in series with the armature circuit; and third, those in which there is a combination of these two circuits. There are in addition a very large variety of each of these classes, different conditions demanding different performance. Furthermore, similar machines may be placed upon three different kinds of circuits, their performances varying widely in each case. These three conditions are: First, the case of special transmission with varying potential and current; second, constant current circuits; and third, constant potential circuits. I will now briefly consider the action of these different kinds of machines on two classes of circuits: First, on the constant current circuit. If a series-wound machine be placed upon such a circuit, the same current passing through the field magnet, it will develop a constant torque, which torque is directly proportional to the strength of the field magnet and the armature. If the masses of iron are large, this torque will be directly proportional to the effective ampère-turns in the field magnet, and the work done will be directly proportional to the speed. If the machine be at rest there will exist a difference of potential at the terminals of the machine equal to the product of the current and the resistance of the machine. When running, however, an electromotive force will be developed in the machine, and the potential at the terminals of the machine will rise by this increment. The work done may be expressed by the product of this counter electromotive force and the current, or $eC$, and is independent of the resistance of the machine. The resistance, however, determines, in combination with the other elements, the total efficiency of the motor. The total energy expended is the product of the difference of potential existing at the terminals of the motor and the current

flowing, or $EC$. The efficiency then is $\frac{cC}{EC}$, or $\frac{c}{E}$, and the heat wasted $(E-c)C$.

When running at any particular speed, the work will be increased directly as the field magnet strength is increased. So also will be the economy. The heat waste with any given resistance in a machine under these conditions is constant. The direction of rotation of such a machine can be reversed by reversing either the armature circuit or the field circuit; if both circuits are reversed, then the machine will run in the same direction. For many classes of work this kind of machine is exceedingly useful, because it admits of a great range of hand control. If such a machine, however, be put on ordinary work, and this work be lightened up, the machine will run faster and faster, and unless the field is weakened or the brushes are shifted to check it, the speed will theoretically increase without limit. Every change of speed and every change of load is accompanied by a corresponding change in the potential which exists at the terminals of the machine. Moreover, on a constant current, the motors being in series with each other and with lamps, this continual variation of potential is apt to cause trouble on the circuit, especially if the machines are not automatic, since, as already stated, with any fixed field the torque is constant, the work done is directly proportional to the speed. The machine has the highest efficiency when running at the highest speed.

With shunt machines, however, the action on the constant current circuit is much different. Here the current is divided in two circuits, such division, when the motor is at rest, being inversely proportional to the resistances of the two parts of the circuit. With such a motor, the field is weakest when the machine is at rest, and its torque or rotary effort is also very weak. As the speed of the machine increases a counter electromotive force is set up, the potential at the terminals of the armature and field magnets rises, the current in the armature diminishes, and that in the field magnet increases.

There are two ways by means of which a constant current motor can be governed. One consists in automatically changing the counter electromotive force by changing the position of the brushes on the commutator to positions more or less removed from their normal one. To this objection is offered because the proper position for the brushes of any machine is at the points of least sparking. The other method consists in varying the counter electromotive force by auto-

matically weakening the field as the load is diminished, or strengthening it as the load is increased. Several methods have been proposed for doing this, generally by the action of a centrifugal governor, but I am now engaged on another system which promises better results.

On constant potential circuits the different classes of motors present other peculiarities. A plain series-wound motor, when there is sufficient iron in the field, has a torque proportional to the square of the current flowing through it. It is capable of exerting a great rotary effort and doing a large amount of work at a slow speed. The range of speed for different loads is, however, great, and the motor is entirely unfitted for ordinary work where steadiness of speed is an object; as the load is diminished the speed increases, and, if thrown off entirely, the motor will run faster and faster, the field continually growing weaker, and the armature all the time accelerating its speed in a vain attempt to generate an electromotive force equal to the initial.

A series motor has some excellent characteristics for work where great changes in speed and torque are desired automatically, these changes being varied inversely.

Since with any given strength of field the torque varies with the increase in the strength of the armature field, and with any given strength of armature the torque varies with the increase in field strength, it follows that with large masses of iron in the armature and field, the torque will vary with the square of the current, and the ratio between the field and armature moment will remain constant.

The following will show the law of variation of speed for a series motor within the limits of the straight line saturation on a constant potential circuit.

If $R$ is the resistance of the armature, and $f$ that of the field, then

$$C = \frac{E - e}{R + f}.$$

$$\text{Work} = e\,\frac{E - e}{R + r} = eC.$$

Work also equals speed multiplied by torque.

The ampère-turns in the field $= nC$. $e$ must vary, then, directly as speed and the field strength; whence

$$\text{Speed varies as } \frac{e}{nC} \text{ or } \frac{e\,(R + f)}{(E - e)\,n},$$

*that is, the speed varies directly as the motor e. m. f., and inversely as the effective e. m. f. or current.*

But the torque varies as $nC^2$ and equals $MnC^2$, $M$ being some constant. Hence we have: Work $=$ Speed $\times MnC^2 = eC$,

$$\text{or Speed} = \frac{e}{MnC};$$

but

$$e = E - C(R + f),$$

whence

$$\text{Speed} = \frac{1}{Mn}\left[\frac{E}{C} - (R + f)\right]$$

so long as the characteristic is a straight line.

On the other hand, the shunt-wound machine will run fairly well on a constant potential circuit. The field, being excited independently of the armature, is constant, and since the load varies with the motor electromotive force, and the field is constant, it follows that the speed must vary with $e$. The torque is proportional to the current in the armature, and the speed will be slowest with the greatest load and fastest with the lightest, that is, when $e = E$. The lower the resistance of the armature, the less the variation in speed, and if sufficiently low with a large ratio of magnetic moments, the motor will practically run at a constant speed.

It is with the third class of motors, when used on constant potential circuits, that the difficulties which are involved in the governing of a motor mostly disappear, and, without the use of any such apparatus as centrifugal governors or movable contacts, it becomes possible to satisfy the most exacting conditions, both as regards efficiency, steadiness of running, power to start under very heavy loads, and freedom from sparking.

I must now particularly request your attention to a seemingly paradoxical statement. In a motor with the armature and field magnet independently supplied, the work which the motor will do in a given time, its economy and efficiency, are all independent of the strength of the field magnet, provided the translating devices intermediate between the motor and whatever is the recipient of its motion are not limited as to the rate of transmission of the motor speed; and that in all cases where a motor is working on a constant potential circuit and not up to its maximum capacity, ***but still above fifty per cent armature efficiency***, in order to increase the mechanical effect either of speed or power, or both, or to compensate for any falling off of the potential on a line, it is necessary to weaken the field magnets, instead of strengthening them, and vice versa.

The strength of the field determines the speed at which a motor

or, $$\frac{e}{e^1} = \frac{mE(R+r) - nf(E-e)}{mE(R+r) - nf(E-e^1)}$$

or, $$\frac{e}{e^1} = \frac{mE(R+r) - nfE + nef}{mE(R+r) - nfE + ne^1f}$$

or, $emE(R+r) - enfE + ene^1f = e^1mE(R+r) - e^1nfE + e^1nef.$

Cancelling, we have

$$em(R+r) - enf = e^1m(R+r) - e^1nf,$$

or, $$m(R+r)(e-e^1) = nf(e-e^1),$$

or, $$\frac{m}{n} = \frac{f}{R+r}.$$

*That is to say, the number of turns in the shunt coil must bear the same ratio to the number in the series coil as the resistance of the shunt coil bears to the sum of the resistance of the series coil and the armature.*

This is my method of winding for a machine of the kind mentioned, and so wound it will be self-regulating for any constant potential up to the maximum allowed by the construction of the machine, and from no load up to the maximum.

There is a feature of motors so wound which may be here noticed.

The ratio of the magnetic moments of the shunt and series fields is

$$\frac{m\frac{E}{f}}{n\frac{E-e}{R+r}}, \text{ or } \frac{mE(R+r)}{nf(E-e)}.$$

But $$\frac{R+r}{f} = \frac{n}{m}.$$

Hence the above ratio $= \dfrac{mEn}{mn(E-e)}$, or $\dfrac{E}{E-e}$.

*That is, the ratio of the initial to the effective electromotive force is the same as the ratio of the moments of the shunt and series coil.*

When $e = 0$ this ratio becomes $\dfrac{E}{E} = 1$; that is, the moments are equal, and this means that, in a perfect machine, *if both coils be closed and in their normal position, for any potential or current, a zero field, or practically so, will be formed, and the motor will either not start at all, or if it does start will run at a very great speed, take the maximum current at any given potential, and do little or no work at all.*

magnet action which is opposed to that of the main coils of the machine. While the main principle is the same, I have a number of different ways of applying it which may be classed as the long shunt, the short shunt, the distorted differential with long and short and compound shunts, and the distorted cumulative-differential with long and short and compound shunts. The first of these was originally proposed by Professor Ayrton, but the proportion of his winding was not the same as my own, because determined experimentally and with field magnets whose magnetic moment was less than that of the armature, while in my motors the converse is true.

In the following demonstration, then, it is to be assumed that the field moment greatly predominates over that of the armature, and also that the characteristic is practically a straight line.

Let $f$ denote the resistance of the main or shunt field coils; $m$ the number of turns therein; $r$ the resistance of the differential or series field coils, and $n$ the number of turns; $E$ the difference of potential at the shunt terminals; $e$ the counter electromotive force set up in the armature; and $R$ the resistance of the armature.

The work done $= e\frac{E-e}{r}$; that is, it depends upon $e$, a variable quantity, and upon the constants $E$ and $r$.

Now $e$ varies with the speed and field, or the effective magnetic moment of the field, but the conditions are that the speed remains constant, hence $e$ must vary with the field alone.

Current in shunt field $= \frac{E}{f}$;

Magnetic moment of same $= m\frac{E}{f}$.

Current in series field $= \frac{E-e}{R+r}$;

Magnetic moment of same $= n\frac{E-e}{R+r}$.

The effective magnetic moment must then be $m\frac{E}{f} - n\frac{E-e}{R+r}$; and the conditions are such that (for two different counter electromotive forces or two different loads)

$$\frac{e}{e^1} = \frac{m\frac{E}{f} - n\frac{E-e}{R+r}}{m\frac{E}{f} - n\frac{E-e^1}{R+r}}$$

In starting, then, it becomes necessary to cut out this governing coil, making the motor a pure shunt motor, or to reverse it and make it a cumulative motor. I use both methods.

What has already been pointed out may be again stated, that the motor will regulate itself perfectly for all potentials so long as we work with a straight line characteristic, *but it must be with a theoretical armature efficiency of not less than fifty per cent, for if we go below this, the governing coil works in the wrong direction.*

A better way of arriving at this same law is as follows:

When running absolutely without load the motor e. m. f. is $E$, and the field is that due to the shunt coil. When running with a load the motor e. m. f. is $e$, and the magnetic field that due to the difference of the shunt and series field moments. We have then, since we assume that our speed is not changed, the equation

$$\frac{e}{E} = \frac{\text{shunt moment} - \text{series moment}}{\text{shunt moment}},$$

or, subtracting each side from unity, we have

$$\frac{E-e}{E} = \frac{\text{series moment}}{\text{shunt moment}}.$$

*That is, the effective e. m. f. is to the initial e. m. f. as the moment of the series coil is to that of the shunt coil.*

But

$$\text{series moment} = \frac{E-e}{R+r}\, n,$$

and

$$\text{shunt moment} = \frac{E}{f}\, m,$$

whence, substituting, we have

$$\frac{E-e}{E} = \frac{\dfrac{E-e}{R+r}\, n}{\dfrac{E}{f}\, m}\,; \text{ or, } \frac{m}{n} = \frac{f}{R+r}.$$

Referring to this equation, we see that if $a$ is the resistance of one mean turn of the shunt coil, and $b$ that of one mean turn of the series coil, then $n = \dfrac{R}{a-b}$.

By varying $a$, and $n$ to correspond, then the motor may be set to run at different determined constant speeds.

Now consider the same class of motors with constant speed, varying load, and *constant current.*

Let the resistances and turns be designated as before. Let $K$ be the constant current. Let $E$ be the variable potential at the terminals of the motor, and $e$ the variable counter electromotive force.

The work done $= \frac{e(E-e)}{R+r}$.

We must eliminate $E$, making it dependent upon $e$ and the constants $R$, $r$, $f$, and $K$, and hence the work can be expressed in terms of $R$, $r$, $f$, $K$, and $e$, of which $e$ is the only variable quality; $e$ depends upon speed and field, but speed is constant. Hence our conditions require that with the same current we make $e$, and hence the work, variable, but by changes in the field alone.

$$\text{Field current} = \frac{E}{f}.$$

$$\text{Armature current} = \frac{E-e}{R+r}.$$

But $K = \frac{E}{f} + \frac{E-e}{R+r}$,

or, $$f(R+r)K = E(R+r) + fE - fe;$$

or, $$f(R+r)K + fe = E(R+r)fE;$$

or, $$\frac{E}{f} = \frac{(R+r)K+e}{R+r+f}, \text{ and } K - \frac{E}{f} = \frac{fK-e}{R+r+f}.$$

Moment of shunt field $= m\,\frac{(R+r)K+e}{R+r+f}$.

Moment of series field $= n\,\frac{fK-e}{R+r+f}$.

Effective moment $= \frac{m(R+r)K + me - n(fK-e)}{R+r+f}$.

Our conditions are such that

$$\frac{e}{e^1} = \frac{m(R+r)K + me - n(fK-e)}{m(R+r)K + me^1 - n(fK-e^1)},$$

or, $$em(R+r)K + mee^1 - nfKe + nee^1 = e^1m(R+r)K + mee^1 - nfKe^1 + nee^1.$$

Cancelling and transferring,

$$m(R+r)(e-e^1) = nf(e-e^1),$$

or, $$\frac{m}{n} = \frac{f}{R+r},$$

*which is the same law as found for constant potential.*

The ratio of moments is $\dfrac{m(R+r)K+me}{nfK-ne}$.

When $e=0$ this becomes $\dfrac{m(R+r)}{nf}$.

But $\dfrac{R+r}{f}=\dfrac{n}{m}$; hence substituting we have $\dfrac{mn}{nm}=1$.

That is, if the motor is at rest and any current is sent through it, a zero field will be produced. This of course follows from what has been already said about the constant potential motor.

The potential $E$ which will exist if $e=E$ and no current is passing in the armature is $fK$, and the maximum work is done when $e=\dfrac{fK}{2}$. To be self-regulating, the motor can be worked up to this point, but not beyond it, for then the regulating coil works in the wrong direction; but this method of regulation is useless for constant current circuits, as is evident from the low efficiency.

We will consider another variety of motor in which this series coil is placed outside the terminals of the shunt coil. The laws governing the action of this machine on a constant potential circuit may be deduced as follows:

Let the same letters of reference be used.

Then the potential existing at the shunt terminals will be $E=rC$.

$$\frac{E-rC}{f}=\text{shunt current};$$

$$\frac{E-rC-e}{R}=\text{armature current};$$

$$\frac{E-rC}{f}+\frac{E-rC-e}{R}=C;$$

$$ER-rCR+fE-rfC-ef=CRf;$$

or, $$CRf+rfC+rRC=fE-ef+ER.$$

Whence, $$C=\frac{f(E-e)+ER}{fR+(f+R)r}.$$

Work done $$=e\,\frac{E-rC-e}{R}.$$

But since $C$ can be expressed in terms of $e$ and constants, the work can be also expressed in terms of $e$ and constants.

$$m\,\frac{E-rC}{f}=\text{shunt current},$$

$$nC=\text{series current},$$

$$m\,\frac{E-rC}{f}-nC=\text{effective current}.$$

$$=m\,\frac{E-r\,\dfrac{f(E-e)+ER}{fR+(f+R)\,r}}{f}-n\,\frac{f(E-e+ER}{fR+(f+R)\,r}.$$

But our conditions are such that

$$\frac{e}{e^1}=\frac{m\,\dfrac{E-r\,\dfrac{f(E-e)+ER}{fR+(f+R)\,r}}{f}-n\,\dfrac{f(E-e)+ER}{fR+(f+R)\,r}}{m\,\dfrac{E-r\,\dfrac{f(E-e^1)+ER}{fR+(f+R)\,r}}{f}-n\,\dfrac{f(E-e^1)+ER}{fR+(f+R)\,r}}$$

or
$$\frac{e}{e^1}=\frac{mE[fR+(f+R)r]-mr[f(E-e)+ER]-nf[f(E-e)+ER]}{mE[fR+(f+R)r]-mr[f(E-e^1)+ER]-nf[f(E-e^1)+ER]},$$

or,
$$\begin{aligned}&mEefR+mEefr+mEerR-merfE+\\&merfe^1-merER-enf^2E+enf^2e^1-enfER=\\&mEe^1fr+mEe^1fr+mEe^1rR-me^1rfE+\\&me^1rfe-me^1rER-e^1nf^2E+e^1nf^2e-e^1nfER.\end{aligned}$$

Cancelling, we have

$$mfR\,(e-e)=nf^2\,(e-e^1)+nRf\,(e-e^1)$$

or,
$$\frac{m}{n}=\frac{f+R}{R}.$$

*That is, the number of turns in the shunt main field bears the same ratio to the number of turns in the series differential field, as the sum of the resistances of the shunt field and the armature bear to the resistance of the armature.*

This is my method of winding for a machine of this character, and so wound, the machine will be self-regulating for any constant potential and for any load up to the maximum allowed, and even with a resistance in circuit and with varying potential.

The same peculiarity exists in those motors which has been pointed out in connection with the first class of differentially wound motors, and this will now be described.

The ratio of the magnetic moments of the shunt and series **fields is**

$$\frac{\dfrac{mE - mr\,\dfrac{f(E-e)+ER}{fR+(f+R)\,r}}{f}}{\dfrac{nf\,(E-e)+nER}{fR+(f+R)\,r}}$$

or, $$\frac{mE[fR+(f+R)\,r]-mr\,[f(E-e)+ER]}{f\,[nf(E-e)+nER]}.$$

If $e=0$, this becomes

$$\frac{mEfR+mEfr+mERr-mrfE-mrER}{f^2nE+fnER}$$

or, $$\frac{mR}{n\,(f+R)}.$$

But $\dfrac{m}{n}=\dfrac{f+R}{R}$.

Hence the ratio becomes $\dfrac{mn}{nm}=1$.

That is to say, if a motor of this character is at rest and the **series** coil in its normal governing position, and the circuit be **closed to the** motor, a zero field, or nearly so, will be produced; for under **these** circumstances the magnetic moments are equal, and either **the motor** will not start at all, or, if it does start, will run at a very great **speed,** take the maximum current at any given potential, and do little **work** or none at all.

This motor with constant speed, varying load, and ***constant current*** will now be considered.

Let the turns, resistance, etc., be designated as before. $E$ **is the** variable potential at the terminals of the shunt field, and $e$ **the cor**responding counter electromotive force.

We must eliminate $E$ and express the work in **terms of** $e$ **and con**stants; $e$ depends on speed and strength of field, but since **speed is** constant, $e$ depends on the field alone.

$$\frac{E}{f} = \text{current in shunt field},$$

$$\frac{E-e}{R} = \text{current in armature},$$

$$K = \text{current in series field};$$

herefore, $$K=\frac{E}{f}+\frac{E-e}{R};$$

whence, $$fRK = ER + (E - e)f,$$

or, $$\frac{E}{f} = \frac{RK + e}{f + R}.$$

Our conditions are

$$\frac{e}{e^1} = \frac{\dfrac{mRK + me}{f + R} - nK}{\dfrac{mRK + me^1}{f + R} - nK}$$

or, $$\frac{e}{e^1} = \frac{mRK + me - fnK - RnK}{mRK + me^1 - fnK - RnK};$$

or, $$emRK + mee^1 - fnKe - RnKe = e^1mRK$$
$$+ mee^1 - fnKe^1\ RnKe^1$$

or, $$(e - e^1)\,mRK = (e - e^1)fnK + (e - e^1)\,RnK$$

or, $$\frac{m}{n} = \frac{f + R}{R}.$$

This is the same law of winding that holds when a machine of the same class is used for constant potential; and the same remarks in regard to the zero field apply as in the former case.

Also, as in the former case, the speed for any given current can be varied by varying the resistance and turns or the effective turns.

*From the foregoing demonstrations it follows that a motor of either class depending for its regulation on this differential winding will regulate with a constant current only when working at less than fifty per cent armature efficiency; and that the same machine with the same winding will regulate on a constant potential circuit only when working at over fifty per cent armature efficiency.*

The laws above set forth are for pure electro-dynamic motors; if there is any permanent magnetism, as in hard cast iron, or where permanent steel magnets are used, the law of winding is modified in so far as the residual or permanent magnetism is the equivalent of an electro-magnetic moment; but in this case, too, there should exist a zero field if the governing coil is normally closed when the motor is at rest.

It should be remarked here that in practice the quality of commercial iron makes some departure from theoretical laws necessary.

As an instance of the effect of reversing the governing coil in starting, if a constant potential motor has the series coil reversed when

the full current is used, there being margin enough in the field characteristic, we would have a field twice as strong as the strongest normal field, four times the strength when the motor is doing its maximum work per unit of time and a momentary rotary effort eight times that existing when the maximum work is on. As soon as the speed comes up, if the governing coil is short circuited and then reversed, the motor will be self-regulating.

On some machines I take another step in overcoming, or rather counteracting the distortion set up by the armature, by producing a distortion in the field magnets which is dependent on precisely the same current that flowed through the armature. I will describe one method only.

Main field-magnet coils are employed in shunt relation to the armature, differential field-magnet coils in series with the armature, and additional cumulative field-magnet coils, also in series with the armature. The main field-coils may be shunted upon the armature alone or upon the armature and both the cumulative and differential series coils or upon the armature or either of the series coils, the other series coil remaining outside the terminal of the main field shunt.

The object sought is to maintain the non-sparking points of the commutator cylinder constant by opposing the distortion of the magnetic field due to variations in the armature current by a counter distortion dependent upon such variations, whereby the magnetic resultant due to the armature and field magnet is unchanged, and the line of parallel cutting of the lines of force or point of least sparking is maintained in the same position.

In accomplishing the counter distortion of the field, the motor used is one in which the field-magnet cores extend in different directions from the field of force in which the armature revolves. The differential series coils are wound or arranged so that their greatest effect is produced on diagonally opposite parts of the magnetic field, and the cumulative series coils, so that their greatest effect is produced on the other diagonally opposite parts. The differential coils are arranged to have a greater magnetizing effect than the cumulative coils. A decrease of load, causing a decreased armature current, tends to shift the magnetic resultant of the armature and field magnet; but this also decreases the magnetizing effect of all the series coils, and, therefore, the parts of the field principally affected by the cumulative coils are weakened, and those principally affected by the differential

coils are strengthened, whereby a distortion of field is produced opposed to that produced by the decrease of armature current, and hence the magnetic resultant—the line of parallel cutting and the points of least sparking—remains unchanged. Thus no shifting of the commutator brushes is ever required, except on account of wear.

I will now consider, from both the technical and commercial standpoints, the different classes of circuits on which motors may be used.

First. Arc light, or constant current circuits, in which the current supplied to the motor is kept constant at a certain number of ampères, ranging from six to nineteen ampères in different systems. The electromotive force at the terminals of the motor varies with the load.

Second. Constant potential, or incandescent light circuits, in which the difference of potential at the terminals of the machines is kept practically constant while the current varies with the load.

Third. Circuits in which the current and the potential both vary, as is the case where there is an appreciable drop or fall of potential on connecting lines somewhat removed from the source of power of a constant potential system, and in cases of special transmission.

I am now operating on all classes of these circuits, but since, because of the small ampère capacity of the current on arc light circuits, any large power must require a great difference of potential at the motor terminals, and variations of power will cause sudden and great changes of potential, the arc light circuits are useful in conjunction with arc lights for transmission of small powers only, or for constant work.

In considering the transmission of power from a general central station as an industry, that is, in a broad and comprehensive way, and not as an adjunct to some system of lighting, and leaving out of consideration for the present special cases of transmission, which forms a class of work by itself, practical and theoretical considerations make it imperative that the constant potential method of distribution is the only safe and feasible one.

It must be borne in mind that I do not agree with those writers who hold that central station distribution in limited areas is confined to "small domestic industries." We have then to deal with large and small powers, varying and constant loads, and the necessity of absolute independence both in operation and regulation of each motor. Furthermore, the motors may be designed for different classes of work, some constant in speed, others variable, and so on.

The only existing constant current circuits are used primarily for

[illegible] and these range [illegible]. The unit of light which [illegible] expenditure of [illegible] greater expenditure [illegible] the tendency is [illegible]

[illegible] this to go [illegible] and a [illegible] permit in [illegible] the size of the [illegible] and [illegible] power—suppos- [illegible] have supplied [illegible]. In other words, [illegible] electromotive force [illegible]. Suppose, now, [illegible] would then be [illegible] supply to it [illegible] ampère [illegible] volts.

[illegible] volts. [illegible] power could be recovered; [illegible]. In other words, [illegible] the transmission of [illegible] even the largest [illegible] and if used in [illegible] any particular [illegible] deal with the trans- [illegible] one-half or even two or [illegible] the element of danger as [illegible] then we can work with an [illegible] transmit units of five, ten, [illegible] power we cannot deal with the [illegible]

[illegible] we have [illegible] put up on certain lines nearly two [illegible]. Suppose this were supplied on 9½ ampère [illegible] than [illegible] of 2500 volts each would be [illegible] probably more, because with units as high as fifteen horse power and this division of circuits, the law of general average come into play in but a very limited manner.

These eight 2500-volt circuits represent the capacity of a 460 arc lamp station, and to deliver the power not a single lamp could be used at the same time. The constant current method of distributing power is the limited and unnatural method; the constant potential, the comprehensive and natural method. This is a fact entirely independent of the question of relative electrical potentials, because on the constant potential circuit we can work at 100, 1000, or 5000 volts, if we please. In short, electrical distribution follows much the same laws that hold in gas, water, and steam distribution.

We may now with profit consider some of the peculiarities which distinguish special cases of power transmission, some of the methods which may be used, and also certain economic problems which are of prime importance. We will first note the behavior of a series-wound motor having a constant torque or load per turn. The motor being at rest, as the e. m. f. of the generator is raised the current $\frac{E}{K}$ increases until the torque is great enough to start the motor against its load. A motor e. m. f. is now created, and the current becomes $\frac{E'-e}{K}$. As the e. m. f. of the generator $E'$ is increased, this current $\frac{E'-e}{K}$ *remains perfectly constant* and equal in value to $\frac{E}{K}$, and the motor increases its speed in the ratio $\frac{E'-E}{E}$.

In considering special cases of transmission, that is, between a single generator and motor, the better method is to use a circuit of variable current and electromotive force, and here, too, plain series machines may be used. These, however, must be definitely related, and I will very briefly touch upon the theory of this method of transmission.

We have the condition that the same current passes through each field and armature. We also have the condition that the speed is constant but that the work is variable. Work may be expressed as the product of speed and torque, and since the speed is constant, it follows that the motor torque must vary directly as the work.

Again, the work may be expressed by the product of the motor e. m. f. $e$ and the current $C$. Since the speed of the motor is constant, $e$ must vary directly as the strength of the field, which, if of low saturation, will vary directly as the current, and if highly magnetized, will vary in a less degree.

If $E$ is the e. m. f. of the generator, and $K$ the resistance of the circuit,

$$C = \frac{E - e}{K},$$

and as above expressed, we have

$$C \propto e \propto E - e \propto C,$$

and

$$\text{Work} \propto eC \propto C^2 \propto e^2 \propto E^2.$$

If the generator be driven at a constant speed, $E$ varies as the [illegible]

If $m$ be the number of turns of wire in the dynamo field and $n$ those on the motor field, then the ampère-turns, or magnetizing forces, are $mC$ and $nC$.

It follows from what precedes that $mC$ should vary with $nC$ in the same proportion. In other words, *the characteristics of the [illegible] should be similar in character between the limits [illegible]*

The efficiency of the circuit being $\frac{e}{E}$, we have the following law, [illegible] *for all loads in the limit of automatic* [illegible]

If the machines are of the same general type, then, when correctly proportional, [illegible] *their size should be the same as the efficiency* [illegible]

It is as well to give here certain general laws concerning the transmission of energy on a complete metallic circuit without leakage, which may be expressed as follows:

First: with any given work done by a motor, loss of power on the line, electromotive force at the terminals of the motor, and distribution, the weight of copper varies as the square of the distance. That is, if the distance is doubled with these given conditions, four times the weight of copper will be required.

Second, with the same conditions, the weight will vary inversely as the square of the electromotive force used at the motor. That is, if using double the electromotive force at the motor, it is necessary to use only one quarter of the weight of wire.

Another way of expressing this is, that if the weight of copper is [giv]en, with any given amount of power transmitted and a given [dist]ribution, the distance over which the power can be trans-

mitted can be increased in directly the same ratio as is the electromotive force; for example, if a thousand pounds of copper is required to transmit a given amount of power with a given loss, and it is desired to double the distance with the same weight of copper, then the electromotive force must be doubled.

Again, with the same cross section of conductor, the distance over which a given amount of power can be transmitted will vary as the square of the electromotive force.

These laws may be expressed in a formula which is of frequent utility in determining the condition on ordinary circuits, and has also a widespread application in special work.

Let $l =$ distance between the generating and receiving stations in feet, plus the sag.

$n =$ number of effective horse power to be delivered on the motor shaft.

$E =$ electromotive force at the terminals of the motor.

$v =$ number of volts fall of potential on the line,

$E + v$ being, of course, the electromotive force at the beginning of the line.

$K =$ efficiency of the motor.

$CM =$ circular mils of conductor.

An electrical horse power is 746 watts, watts being the product of current by electromotive force. Then for any horse power, a motor efficiency of $a$, and an e. m. f. of $E$ at the motor terminals, we have the number of ampères equal to $\frac{746\,n}{Ea}$.

Allowing 10.5 ohms as the resistance per mil-foot of copper, the total resistance would be $\frac{21\,l}{CM}$.

From the above we have

$$v = \frac{746\,n}{Ea} \times \frac{21\,l}{CM}$$

or

$$CM = \frac{15{,}666\,nl}{Eva}.$$

Let me give you a practical illustration. Suppose we have a motor the efficiency of which is ninety per cent at 400 volts electromotive force and when developing ten horse power, and that we wish to transmit this ten horse power 5000 feet from a station, and elect to lose about nine per cent on the line.

Our initial electromotive force will be 440 volts, and we would have

$$CM = \frac{15{,}666 \times 10 \times 5000}{400 \times 40 \times .90}; \text{ or}$$

$CM = 54{,}396$, which is about equal to a No. 4 B. W. G.

Again, suppose we wish to transmit five horse power over a distance of one mile on a complete metallic circuit of 45,000 *CM*, allowing five per cent increase of length for sag, and no leakage. Suppose, further, that the initial line potential be 300 volts, and that we wish to have 250 volts at the motor terminals, it is required to find the commercial efficiency which the motor must have.

Transposing our formula we have

$$a = \frac{15{,}666\, nl}{EvCM},$$

and substituting,

$$a = \frac{15{,}666 \times 5 \times 5544}{250 \times 50 \times 45{,}000} = 76 \text{ per cent.}$$

This formula is useful in determining what we cannot do, as well as what we can do. For example, if we made the condition ten horse power, all others remaining the same, the commercial efficiency of the motor would have come out 152 per cent, a most excellent machine indeed, and yet it is precisely this absurd thing that people practically say they will do in many of the statements which are made in relation to this subject. No science admits of more easy determination of conditions by plain and simple laws, and none brooks less violation of them.

In considering the transmission of power, a very curious fact may be demonstrated by a formula for determining the minimum cost of plant, where the amount of power at the generating station is practically not limited, and where there is no line loss from leakage, the line loss being measured simply by the fall in potential.

The cost of a plant of this character can be divided into four parts, that of the motors, the line erected, the dynamos, and the power plant, whether water or steam. I will assume that the cost of the dynamos and motors cost the same amount per horse power or other unit, no matter what the electromotive force used. While this is not strictly true, for all practical purposes, with large units, and speaking from the commercial standpoint, it is so. This being the case, for any given power the cost of the motor is a constant independently of the potential used. The greater the loss on

the line, the less the cost of the conductors, but the greater the cost of the generators. On the other hand, the less the loss on the line, the greater its cost, but the less the cost of the generating plant. It follows then that the least cost to the contractor is determined when the increment of saving in the cost of the generator is equal to the increment in the cost of the line.

We have for the size of the wire necessary to transmit energy on a complete metallic circuit without leakage, the formula already given,

$$CM = \frac{15,666\,nl}{Eva}.$$

If $d$ equals the weight of one mil-foot of copper, then the weight per foot of our conductor would be

$$\frac{15,666\,nld}{Eva};$$

and the total weight for length $2l$—this $l$ being of course the actual distance plus the sag of the wire—would be

$$\frac{31,332\,nl^2d}{Eva}.$$

If $b$ is the cost in cents per lb. of copper in line erected, we have for the cost of the line, which will of course depend upon local conditions,

$$\frac{31,332\,nl^2db}{Eva}. \qquad (1)$$

Let $E$ be the e. m. f. at the terminals of the motor; $v$ the fall of potential; $\beta$ the commercial efficiency; $E'$ the e. m. f. of the generator, and $n$ the number of horse power developed by the motor.

Then $\frac{E'}{e}$ = ratio of the watt capacity of the generator and motor, $\frac{n}{a}$ = energy delivered to the motor terminals, $\frac{(E+v)n}{Ea}$ = energy delivered to the line, and $\frac{(E+v)n}{Ea\beta}$ = the horse power delivered to the generator.

If $K$ = cost in cents of the generators per horse power required to drive them, and $L$ the cost per horse power of the steam or water plant, then the cost of the generating plant complete would be

$$\frac{E+v}{Ea\beta}\,n\,(K+L);$$

and the cost of the total plant when $M$ is the cost of motor per horse power developed,

$$TC = \frac{31{,}332\, nl^2db}{Eva} + \frac{(E+v)(K+L)n}{a\beta E} + nM, \qquad (2)$$

which, differentiated for a minimum with $v$ as the variable, gives as a condition

$$\frac{31{,}332\, l^2db}{v^2} = \frac{K+L}{\beta},$$

whence,

$$v = l\sqrt{\frac{31{,}332\, db\beta}{K+L}},$$

or, substituting for $d$ its value .000003027o5,

$$v = .308\, l\sqrt{\frac{b\beta}{K+L}}.$$

In other words, *with fixed conditions of cost and efficiency of apparatus, the number of volts fall to get the minimum cost of the plant is a function of the distance alone, and is independent of the total electromotive force.*

The value of this will at once become apparent. Suppose at some place where we wish to transmit a large amount of power over a considerable distance, the cost of the water plant, that is, of the turbines, sluice-gates, water-channel, building and shafting, should cost $50 per horse power; that of the generator $35 per horse power; copper, per pound, erected, 20 cents; and further, suppose our dynamos to have an efficiency of 90 per cent. Our formula then becomes

$$v = \frac{l}{70}.$$

If the distance be five miles, the number of volts fall in potential would be

$$v = \frac{5 \times 5280}{70} = 377 \text{ volts.}$$

If 500 volts be used at the motor, the e. m. f. at the generator terminals would be 877 volts; and if 1000 volts at the motor, then 1377 at the generator.

While this fall of potential is independent of the total electromotive force, this last of course determines in part the total cost.

A consideration of the above formula and the investment and cost per horse power in any particular locality will quickly determine the practicability of transmitting power by electricity rather than generation by a local steam plant.

The commercial efficiency of the circuit may be expressed by the equation

$$\frac{Ea\beta}{E+v}.$$

It follows that, *to maintain the same commercial efficiency and the minimum net cost of plant, the e. m. f. at the terminals of the motor and the generator must be increased in precisely the same ratio as is the distance.*

Let us look at the problem in another light.

Suppose with the costs of material as above given we want to get a net commercial efficiency of sixty per cent on a ten mile circuit, with dynamos and motors whose *couple efficiency*, $\alpha_{,}\beta$, if I may use the term, is 80 per cent.

Substituting in our formulas the values given, we have as conditions

$$\frac{E}{E+v} \times \frac{4}{5} = \frac{3}{5},$$

or,

$$\frac{E}{E+v} = \frac{3}{4} \text{ or } E = 3v,$$

and

$$v = \frac{l}{70} = \frac{10 \times 5280}{70} = 754,$$

whence,

$$E = 2262 \text{ volts},$$

and

$$E + v = 3016 \text{ volts}.$$

Under like conditions, if the distance is only five miles,

$$E_1 = 1131,$$
$$E_1 + v_1 = 1508, \text{ and so on.}$$

We can easily make a general formula. Let $\lambda =$ the commercial efficiency required. Then we have

$$\frac{E\alpha_{,}\beta}{E+v} = \lambda,$$

or,

$$v = \frac{\alpha_{,}\beta - \lambda}{\lambda} E.$$

Also,

$$v = .308\, l \sqrt{\frac{b_{,}\beta}{K+L}},$$

whence,

$$E = \frac{.308\, l\lambda}{\alpha\beta - \lambda} \sqrt{\frac{b_{,}\beta}{K+L}},$$

which gives the e. m. f. at the motor terminals, and from this all other elements can be deduced.

From these formulae we see that, with fixed conditions not only is the number of volts fall of potential dependent on the distance alone, *but with any fixed commercial efficiency the e. m. f. at the*

*motor and generator terminals is also dependent simply on the distance.*

Again, *the number of volts fall and the motor e. m. f. vary inversely as the square root of the cost of the generating plant.*

Another fact is important. Since the circular mils vary inversely as $Ev$, *the size, weight, and cost of the wire vary directly as the cost of the generating plant.*

One of the most important applications of the principle of reversibility which I pointed out as characterizing dynamos and motors is its possible use in braking trains. The electromotive force depends upon the strength of the field and the velocity of the armature, and is independent of everything else. It is evident, therefore, that if the strength of the field magnet is increased, the motor electromotive force is also increased; and if the increase of field strength is continued, the initial and counter electromotive forces will become equal, and then the counter or motor electromotive force will predominate. The propelling motor will now become a generator and give current to the line, and its mechanical effects are reversed, so that it brakes the train instead of propelling it, and the current generated by it and the braking power or reversed mechanical effect are now controllable by further increasing or by rediminishing the strength of field.

It will be seen that mechanical energy is received by the reversed motor according to the mass of the train and its velocity. If a train should start on a down grade unprovided with a brake, the energy of falling would tend to increase its speed; but when this method of braking is used, this mechanical energy is transformed in the machine into electrical energy delivered to the line, and augmenting that supplied from the generating stations to the other trains, which may be moving upon up-grades or on levels.

When it is desired to slow down a train on a level grade, the field is increased, as before, until the counter electromotive force predominates over the initial, and the energy stored up in the moving train is exerted to run the machine as a braking dynamo. As the train slows, however, the diminution of speed of the armature will tend to diminish the counter electromotive force, and the increase of field strength must therefore be continued, so as to still maintain the counter electromotive force above the initial and keep the machine running as a generator as long as practicable, when other methods of braking, as, for example, closing the armature circuit on a local regulating resistance or brake circuit, may be used.

I will give an instance to show how effectively this method may be employed, premising that when large masses of iron are used in the field magnets, the strength of the field can be varied within effective limits two or three hundred per cent, and also that a well constructed armature can carry for a short time fifty, seventy-five, or perhaps even one hundred per cent more current than it can stand for any long run. Suppose the armature of a motor to have a resistance of three-tenths of an ohm, with field coils in shunt relation, and provided with suitable means for varying their strength. Suppose the initial electromotive force to be five hundred volts, and forty horse power to be required from the motor when running at its maximum. Allowing for losses in conversion, this forty horse power would be about thirty-two thousand watts. The counter electromotive force would be four hundred and eighty volts, the effective electromotive force twenty volts, and the current sixty-seven ampères. The electrical efficiency of the armature would be ninety-six per cent. Suppose the strength of the field to be increased about four per cent, the speed remaining the same, the motor running on a down grade; the counter electromotive will be increased to five hundred volts, and the motor armature will then be perfectly passive electrically, neither taking from nor giving to the line. Let the field strength be increased again one per cent, and let the increase be continued in the same ratio. The result is shown in the following table:

| Total field increase. | Current to line. | Approximate energy required from train, allowing for losses. |
|---|---|---|
| 5 per cent. | 13.3 ampères. | 9.5 horse power. |
| 6 | 29.3 | 20.9 |
| 7 | 45.3 | 32.7 |
| 8 | 61.3 | 44.7 |
| 9 | 77.3 | 56.9 |
| 10 | 93.3 | 69.3 |

From the above it will be seen that by simply increasing the field strength one twenty-fifth part, the machine is converted from a motor driving a train with forty horse power of effective work, to a perfectly passive machine, allowing the train to run absolutely free. Then by increasing the field one one-hundredth part the motor at once exerts a positive braking force, and on an increase of about eight and one-half per cent above its original strength it will give back to the line current equal to that which was originally taken from it, sufficient, evidently, to run some other motor of the system which may at that time require

that amount of current; and by increasing the original field ten per cent the machine acts as a dynamo, requiring more than fifty per cent more energy than is demanded to run it as a motor developing forty horse power.

This method of braking, it will be seen, is under perfect control, and it is the most economical system possible for an electric railway, since whenever a train descends a grade, and whenever a train stops, the energy stored up in the moving train is delivered in the form of electrical energy upon the line.

Consider for a moment what occurs on a steam railway train making frequent stops at short intervals. Suppose it to be ascending a grade, then the engine exerts more than its average amount of power. When it reaches the top and enters upon a down grade, steam is shut off, and when the train begins to run faster than is desired, the brakes are put on, and the energy of the train is then converted into heat on the rims of the wheels and on the brake-shoes. In other words, all the energy in excess of that necessary to run the train on a level which has been required to climb the grade is now thrown away in going down the grade, instead of being utilized, as in this system; and, furthermore, additional steam is actually required to check the tendency to augmented speed. Then when the train approaches a stopping place, or whenever it is necessary to slow the train down quickly, steam has to be employed to actuate the brakes, and all this additional power is simply thrown away. By the electrical method of working, the greater part of this loss may be entirely obviated.

It is true that not all of the energy will be converted into electricity, but a large proportion of it will be.

On a double-track road, with both tracks supplied from the same main circuit, the energy given to one track is also communicated to the other. The up-grades on one track being always balanced by the down-grades on the other track, it is evident that the total up-grade of the whole system is equal to the total down-grade thereof. Therefore, energy being expended on the up-grades, and given out to nearly the same extent on the down-grades, the energy required in the system is that sufficient to move a train upon a level with a slight percentage added; but on a steam railway the energy required is not only that sufficient to run a train on a level, but, in addition, that necessary to raise it from the lower to the higher grades on both tracks, no matter how many of such grades there may be.

Suppose the Third Avenue " L" road of New York were equipped with electric motors, let us consider what the application of this method of braking would mean. There were not long ago, at about six o'clock in the evening, sixty-three trains in operation at one time on about eight miles of double track. The maximum capacity of the engines is about one hundred and eighty horse power, giving an aggregate of 11,340 horses. The work, however, is continually varying, because the trains have to make stations about one-third of a mile apart in eighty seconds, and the average work done is only about seventy-one horses, or 4473 horses total.

Yet the wasteful character of the expenditure is shown by the fact that fifty-nine per cent is expended in overcoming the inertia of the train in getting underway, twenty-four per cent in lifting it on grades, and seventeen per cent only in traction. If the 4473 horse power which represents the average were supplied by electricity in the ordinarily proposed methods, with a recovery of say sixty per cent, then there would be required not less than 7455 horse power at the central stations. By using the system of braking I have described on down grades and in stopping, enough of the energy of the train can be reconverted into electricity to entirely make up all the losses of conversion, transmission and reconversion, so that at the central station only about 4473 horse power would be required, a saving in investment, and coal consumption of $7455 - 4473 = 2982$ horse power.

Instead of the current being all supplied by the main generating station at one or more points, it would be supplied from nearly as many additional moving stations distributed along the whole line, as there are trains slowing down or running on down grades. With any given size of conductor, the loss would be much less, and, with the same losses, the sizes of conductors could be very much reduced.

I have thus shown how, in the application of motors to both stationary and railroad work, the control of the motor electromotive force is the key to the control of the power and speed. I will give one or two more illustrations of the practical character of this theory and how it may be utilized. In our factory one of the methods that we have of testing motors is the following. The power which we have is limited. We sometimes wish to test a number of motors together, and in doing so to develop an amount of power which it is impossible for us to spare from our shafting. Suppose, for example, that we wish to test two 20 horse power and two 7½ horse power motors, an aggregate of about 55 horse power. One of these 7½ horse power motors is

driven as a dynamo. This is electrically connected to the second one, which is driven from the first as a motor. Overhead, we have a line of countershafting, on which are three pulleys. Our two 20 horse power machines are belted up to these pulleys, and likewise the 7½ horse power motor. The like terminals of the large motors are then connected together, and an ampère meter put into one branch of the circuit. One terminal of each field is likewise connected to its proper line, and the other terminals of these fields are brought to the movable levers of a three-part circuit changing switch. One contact is carried to the other line, and between it and the other two is inserted a variable resistance, which, in the middle position of the switch, is short circuited. We have, then, the two large motors connected in an *electro-mechanical couple*, and to the same mechanical shafting is connected a third motor. The dynamo being started, the switch set in the middle position, the motor is speeded up, which sets the countershafting in operation, and drives both the 20 horse power motors as dynamos, each exciting its own field. If the machines are symmetrical, no current whatsoever will pass over the branch connecting the two; they are simply in the position of two dynamos in parallel circuit with each other, with no external circuit and no path over which the current can flow, except that through their field magnets; consequently, very little power, save that of friction, is taken. The switch being moved in one direction, the resistance is thrown into the field of one machine. The electromotive force which it develops at this particular speed is now reduced; it becomes a motor, and current will flow over the connecting mains from the other machine, which is now a dynamo, which current is expressed by the quotient of the difference of the electromotive force of the two machines by the resistance of the two armatures and the connecting mains. By varying this resistance, this current can be made of any value up to the limit. We have here, then, one machine acting as a motor, and driving on to the countershafting with a certain number of horse power, this countershafting driving the other machine as a dynamo with a certain greater amount of horse power, this second machine furnishing the current which operates the first as a motor. The deficit, or loss of efficiency between the two machines, is made up by the third 7½ horse power motor; in other words, one machine is driving the other electrically as a motor, and the motor through the countershafting is driving the first one mechanically as a dynamo, the deficiency being made up

as I have just said. By reversing the switch, the resistance is first cut out of the field, and then thrown into the field of the opposite machine. This machine now becomes a motor, and the other machine becomes a dynamo. This reversal is not instantaneous, because it takes time for the field magnets to charge and discharge. The ampère meter will drop to zero, and will then rise again progressively.

This method of testing can be used for two purposes, one for testing the actual horse power developed and the *couple efficiency*, which can be done by measuring the current, the electromotive force between the machines and the horse power delivered to the shafting by the third motor, and for the other purpose of testing simply the heating capacity of the armature coils with a given number of ampères. For this latter purpose it does not matter practically whether the machines are run at their normal speed and generate their normal electromotive force, or whether some lower electromotive force is used. If a lower electromotive force is present, it simply means that there must be a greater ratio of difference between the field magnet strengths and a larger resistance used with the reversing switch.

This method of testing, where there can be an instantaneous and controllable reversibility of the dynamo and motor by the mere touch of the finger, is probably one of the most beautiful, as it is one of the most useful, applications of this characteristic of machines. By it we can test motors of a capacity of, say, fifty-five horse power, with a belt expenditure of about eight or ten horse power.

A similar method of testing can be used in testing the dynamos employed on alternating circuits. It is now customary in testing large machines, say one thousand lights capacity, to use banks of lamps or artificial resistances to test their capacities. Mr. Hopkinson pointed out, some five or six years ago, that two alternating-current machines could be operated in multiple circuit, but could not be operated in series, and one of the practical things which have been developed is this: that if two alternating machines are run in multiple circuit, before they can be thrown together in safety that they have to be brought into unison. It must be remembered that in an alternating-current machine the variation of electromotive force instead of being two or three, or four or five per cent, as with a constant-current machine, is of the greatest degree. With a one thousand-volt machine, the electromotive force is first as one thousand volts positive and then one thousand volts negative, and this

may occur a hundred times a second. If two machines which are not in unison are thrown together on the same circuit, one is retarded and the other is accelerated, the one acting as a dynamo and the other as a motor, and in the twinkling of an eye they are brought into unison with a report and a shock so sharp that it has for the uninitiated a startling effect, and is, of course, a very severe wrench upon the machines. It is common to excite the field magnets of alternating-current machines by separate exciters. If they run at the same speed, have the same characteristics and have field magnets of the same strength, then when they are in unison both machines will act as dynamos, and neither will take or give current to or from the other. If they are out of unison, then because of the rapidity of the pulsations of these phases and the great change of electromotive forces in the machines they will necessarily come together. One cannot be run as a motor and the other as a dynamo practically by maintaining them out of unison.

Let the two machines be, however, started together with zero fields, and when running at their normal speed let the field magnets be gradually strengthened. The machines will come to unison without trouble. If now, when thus running in unison, the exciting circuit be arranged, as is very easy, so that the field magnets of either can be weakened, then the phase curve of one may be made lower than that of the other by any required degree. The pulsations will be the same in number, they will change in character at the same instant and in the same way, but since there is a difference of electromotive force, the one developing, say, five per cent more than the other, then one will be running as a motor and the other as a dynamo. Both can be driven off the same line of countershafting or engine, and two one thousand-light machines can be tested to their full current-carrying capacity with a very small fractional part of the power which they each separately require, and their dynamo and motor phases can be reversed with the same rapidity and with the same ease and safety as I have described with the constant current machines.

You have been kind enough to express a wish to hear something of the commercial development that has taken place, and I will give you briefly some facts showing how entirely beyond the visionary realm the transmission of power has gone. Some three years ago, the first electric motors which I put into practical use in territory outside of my own jurisdiction were sent to Lawrence, Massachu-

setts, and one of these was used in an isolated plant for operating a cotton elevator in the Pemberton Mills. Since that time the work has gone forward steadily, at first slowly, and of late with a rapidity which has exceeded my most sanguine expectations.

The first companies on whose circuits what are called the constant speed motors were first introduced were the circuits of the Edison Electric Illuminating Companies, and now a very large number of these companies, as well as many others, are coming to realize that one of the most important matters to which they can give their attention is the development of the use of motors for all industrial purposes within the range of the territory covered by their conductors. The result has been that these machines are now being introduced in the United States in the cities of New York, Chicago, Boston, Des Moines, Elgin, Oskaloosa, Pittsburgh, Chester, Williamsport, Lancaster, Shamokin, York, Detroit, Topeka, Hutchinson, New Orleans, Cleveland, Cincinnati, Springfield, New Brunswick, Fall River, New Bedford, Milford, Taunton, Lawrence, Woonsocket, Fort Meyer, Waterbury, Annapolis, St. Louis, Abilene, Pawtucket, Syracuse, and also into Canada, the Argentine Republic, Austria, Germany, Italy, and Japan, and they are being applied to every possible use. In Boston there have been introduced within the past few months nearly sixty of these machines on one circuit, varying from one-half to fifteen horse power in capacity. In New York there are about sixty machines in operation, and the number is now rapidly increasing.

The position I early took in this matter was briefly this: that electricity could fill the field in a far more complete and satisfactory manner than, but in very much the same general way, as the distribution of power from a central station by means of gas, steam, water, or compressed air. The use of any of these elements involves engineering problems. To be successfully solved, not merely as a scientific fact, but in a commercial sense, every part of such system should be in thorough accord with every other part. It is not sufficient that there should be a good dynamo, or a good system of distribution, or a good motor, but that they should be definitely related, the units, the distribution, the area of the distribution, the sizes of the conductors, and the electromotive forces being determined with reference to each other, and to the ultimate demands to be made upon the central station. Nor could any elements of such a system be in doubt. It goes almost without saying that large engines can be operated and large

powers developed under as little general supervision as smaller ones, and under far less supervision than several units of small powers. The cost of the generation of power is much less in large engines, both in the amount of coal and water used and the matter of attendance, and also in the general expense. It follows, then, that if the power of a manufacturing district can be centralized, it can be developed at a much higher efficiency and at a very much lower cost than where it is being generated in a large number of units. If, after such centralization, it can be distributed to a large number of users in the district with only a moderate loss, then supposing only that the same amount of power is sold as is generated in the central station, this plan of generating power would still have the advantage, in point of economy; but when we take into account, as shown by our records, and as is being borne out by practical experience every day, that under the circumstances a central station can take advantage of a low average percentage in use of the capacity of machines, it then becomes apparent that if the system is properly constructed and operated there is not only not a loss, but a great gain in the centralization of steam power; and this will hold true whether dealing with a central station of one hundred or ten thousand horse power, and, if operating under proper electromotive forces, whether the district is a square mile or ten square miles. In fact, electricity is the most convenient, tractable, yet powerful means of carrying and distributing energy or motion from one point to another. As a means of transmission, it has greater advantage over steam, water, gas, or compressed air, in that the system of conductors is far more flexible in its arrangements, and capable of much greater ramifications than any of its competitors. It can be operated under much higher relative pressures or potentials than the other methods of conducting power, and hence it can be distributed with very much smaller conductors and much smaller investments and losses. Of course the truth of this depends upon the efficiency of the different parts of the system.

There are three ways in which power is lost after it is generated in a steam engine and delivered to the dynamo pulleys. The first is in the dynamo. This has now been brought to such a high state of efficiency that there are several good types of machines which have a commercial efficiency as high as ninety per cent. The second loss is that which occurs in the distributing wires or conductors, and this depends upon the electromotive force used, the distance over which the current is distributed, the distribution and arrangement of the

conductors, and the amount of current carried. This loss should not exceed in a general district over ten per cent. The third loss is in the motors, where the energy of the electricity is reconverted into mechanical power. Motors vary in their efficiency. To truly answer the commercial conditions, the current used should be almost directly proportional to the work done. The higher the efficiency of the motor, the more nearly will this law hold. Small machines are not as efficient as large ones, nor is every motor of equal efficiency under all loads; but in large machines the efficiency under full loads is now about ninety-one per cent.

As between two motors of differing efficiency, with that of the lesser efficiency not only would the size of the conductors which would be needed in a particular area to distribute a given amount of mechanical work be much increased, and the area over which any given amount of power could be distributed with a given weight of conductor be very much smaller, but also the capacity of both the dynamos and engines in a central station would have to be very materially increased to get a given output of mechanical work. Increased area, lessened weight of copper, greater recovery of power, and a larger amount of mechanical output, as well as a greater excess capacity of motors, and a less proportional investment in central station appliances and equipments—all these are in favor of the motor having the highest efficiency. The effect upon the lights where they are supplied from the same circuit is also very much less marked with motors of higher than with motors of lower efficiency. In transmitting power over long distances, even in single units, any increase whatsoever in the efficency of the motor or dynamo becomes exceedingly important, because the investments in conductors are very large.

Theoretical conclusions, however, were not of sufficient weight, nor were they generally understood, and one of the greatest difficulties we met with in the introduction of motors was that of determining a method of charging for power, because, on account of the lack of knowledge of the character of the machines and the variable work which they have to do, a contract basis seemed at first inadvisable, and the ordinary current rates for lamps seemed exorbitantly high. Few managers could rid themselves of the notion that, because there was a loss, first in the dynamo, then in the conductors, and finally again in the motors, covering an aggregate of about thirty-five per cent, that it would be impossible to compete with steam when supplied directly. In order to determine these facts, and to prove to

people who were selling power, not only that there was not a loss, but actually an apparent gain in the transmission from a central station; that motors were not to be treated as toys, but as important factors in the industrial arts, and that they would be justified in making a charge for electric power service based upon the sensible method of a contract—records were obtained and calculations made something after the following manner: After several motors had been put into use, we sent out a blank circular requesting, among other things, the number of hours' use which the motors averaged every day, the class of duty, and also the monthly payments, then mostly made on a meter basis. The reports were varied. Some of the records extended over considerable periods of time, and they established the fact that motors, as a rule, do not average over thirty-three per cent of their capacity for the ten hours of a working day. This, in fact, is a large average. This may to a great extent be understood from the following statements: A motor is absolutely automatic. The total current used in machines of high efficiency is almost directly proportional to the work done at any instant. The result is that if the work slacks for a moment, so also does the current, and in nearly the same ratio. Almost all work is spasmodic in character. Motors have to be put in for their maximum capacity, but not one class of work out of a hundred offers continuous duty. Some motors are stopped, and in others which are running the work is constantly varying from the maximum to the minimum. An illustration of this may be cited in the case of elevators. If twenty elevators, each requiring a maximum of five horse power, were driven from the same line of countershafting, they would not require an engine of over forty horse power, because some would be going up, some going down, others standing still, and in not two cases out of the twenty would simultaneous trips be made, while in not one trip in five hundred would an elevator be hoisting its maximum load from the basement to the loft. Comparison also may be made with existing incandescent light plants. Practical experience shows that not over fifty-five or sixty per cent of the total number of lights connected on a station are used at any one time, although it is possible to use them all. But incandescent lamps when they are in use take their full amount of current. Not so with motors. A certain percentage of the motors, just as with the lights, would not be in use at all, and in most of those in use the current would be continually varying, just as if the lights of an incandescent light station were being

turned up and down from one to sixteen candle power, as well as many of them being turned out. The recovery in an ordinary district with eighty-eight to ninety per cent of the power delivered to the dynamo pulleys converted into electricity on the line, and ten per cent loss in distribution, is about sixty-five per cent. This sixty-five per cent, however, where the work is distributed, is only thirty-three per cent of the capacity of the motors for which power can be contracted. In other words, for every one hundred horse power in a central station, sixty-five horse power at any one instant can be delivered under an ordinary distribution, and this sixty-five per cent is only one-third of the power which can be contracted for, provided there are a large number of motors in use. Of course, where only one motor can be used, then sixty-five horse power only would be obtained, but the object of a central station is to take advantage of the intermittent character of the work, and that it can be done is shown by the records which we have of a large number of motors in use.

The future, then, of motors in connection with central stations is assured, but the application of motors to stationary work, or more properly in combination with centres of supply such as the ordinary stations for electric lighting and power, is but one field, although a large one. There are many special fields of work, each of which demands large capital, and offers a wide range of application. Among these may be mentioned the application of the transmission of power to mining works. At present, in single plants, both in the mining of the common and of the precious metals, immense sums are invested in elaborate systems for the transmission of power by compressed air, single plants sometimes costing as much as a half a million dollars. Such a system of transmission must necessarily be costly. Not one case exists in which electricity could not be better used and with a very much reduced investment.

The transmission of power in single units for a variety of purposes too numerous to mention, such as, for instance, the operation of the transfer tables of the C., B., and Q. Railroad at Aurora, and the operation of overhead cranes, is itself a field requiring a great deal of thought. Some idea of the progress made may be gathered from the fact that we have now about twenty-five or thirty different types and classes of machines, and I know that the near future will require fifty or seventy-five.

Again, the substitution of motors for horses in street car work, using in some cases the conduit, in others the overhead wire, and

others the storage battery, is now rapidly coming into favor. On the two latter classes of work we are now actively engaged, and are just at present much interested in the most extensive electric railway system which has ever been contracted for, that of Richmond, which comprises forty cars and eleven miles of track. The great margin between steam and horse power gives ample room for increased efficiency and lessened cost of operation, especially where a number of cars are in operation, because here, as in regular central station work, the apparent output of power will be greater than the actual power of the central station, and, unlike horses, the motors do not require to be fed for twenty-four hours in the day independent of whether they are being used or not.

In one sense, that of size, the most important immediate experiment in which I am engaged is the development of motors for application to the movement of heavy trains on the elevated railroad. I was engaged last year for a considerable period in carrying on experiments on one of the branches of the elevated railroad, during the progress of which one of the standard elevated railroad cars, on a heavy grade and with a current of about six hundred volts potential, was handled under all speeds up to twenty-one miles an hour entirely by the motors, and without the use of hand-brakes, the practice of the recovery of the energy of the car, of which I have already spoken, being there very thoroughly developed. We have now stopped this experiment and have under way the largest apparatus of the kind ever undertaken. This consists of a motor car of special construction, which is designed partially for passengers, and is intended to haul itself and five or six other cars; in other words, a hundred and forty ton train, and this at speeds as high as twenty-eight miles an hour. The middle portion of this car is to be used for passengers, but each end is reserved for the engineer and for duplicate controlling apparatus. Under each end of the car is a heavy iron truck fitted with two pairs of forty-two inch Krupp wheels and five-inch Midvale steel axles. On each axle is to be placed a duplex motor, the normal capacity of which is seventy-five horse power, but which can be worked up to a capacity considerably higher than this. Each motor is centered on the driving axle and drives from each end of the armature. Each motor weighs four tons. The armatures, of which there will be eight altogether, are about eighteen inches long and seventeen inches in diameter. Each of the eight field magnets with its wire will weigh at least a ton. The total weight of the car with passengers will

be about thirty-two tons, but it is distributed over the entire distance between two columns. With a tangential strain on each armature of only about twelve hundred pounds, there will be a draw-bar strain of nearly 13,000 pounds; and this is not by any means the full capacity of the motors. The total power of the motors on this car will be double that of the heaviest locomotive on the road, and the traction coefficient more than twice as much. It will be some months before this is ready, because the work is being elaborated in great detail.

One of the most important applications to which I may call the attention of the gentlemen present is that of the use of electric motors on board ship. The uses to which motors can be applied on a man-of-war are numerous. It will probably be argued by many, when the proposals are made to carry on certain operations by means of electricity, that there is some doubt as to their practicability in so complex an organization and one subject to so many peculiar conditions not met with elsewhere as is a man-of-war. Similar objections were made a few years ago when it was suggested that the incandescent electric light ought to be introduced in the place of the then existing system of lighting. In 1881 I made some efforts to introduce the incandescent electric light on board our ships, and afterwards in 1882 I attended an exhibition at the Crystal Palace, Sydenham, England, and being required to report upon the progress of electric lighting, made as strong a report as I could in favor of this innovation. Whether this report had any weight or not, of course I do not know, but it seems that most of the objections which were raised against electric light proved unfounded, for various systems are being introduced and are giving satisfaction, and so thoroughly satisfied are officers that the proper method of lighting ships is by electricity that few of them would to-day think, for one moment, of seeing the old days return with their antiquated, unpleasant and unhealthy methods of illumination. So may we look upon the application of electricity as a motive power to a great variety of uses on board ship, and that with far more certainty of operation, more ease in manipulation, than in many machines now used. Few people not acquainted with the actual conditions met with on board ship realize the number of small engines in use and the variety of purposes to which they are applied. Steam has superseded hand steering apparatus; steam ventilation takes the place of wind-chutes; blowers, exhaust fans, and pumping machinery are driven by steam; ashes are hoisted by its agency. Shell hoisting

and gun training, which is now performed sometimes by hand and again by pneumatic, hydraulic, or steam apparatus, will certainly, sooner or later, be better done by means of electro-motors. In fact we have been asked already by the Department to submit designs for operating the new 8-inch rifle gun for the Chicago, and are now working on these; the motor will be carried beneath the gun inside the carriage and the training will be under perfect control. Of course I do not say that the first experiment of this kind will be entirely successful, or that it will be devoid of objections. A perfect apparatus in this, as in any other line, must be developed by the process of evolution. It is not always possible to foretell every condition which will be met; but failures are simply the keys to success. The hoisting of shell and other ammunition, now done laboriously and uncertainly by hand, can be better done by positive acting electro-motors which will be under perfect control. Centrifugal pumps, with their rotary movement and high speed, and likewise fans and exhausters, both for ventilation and for forced draft in the furnaces, will be run by motors. It may be urged that there is a liability of accidents occurring with apparatus of this nature. In answer we can say that duplicate parts are easily carried and injured portions quickly replaced—if anything, more quickly than in any steam apparatus. One of the great advantages of the use of electricity for these purposes will be the avoidance of a great deal of heat now caused by carrying steam pipes all over the ships. Steam steering gear is now operated in a clumsy, uncertain method from the forward and after pilot houses by long lines of countershafting and gearing which, because of the general structure of the ship, cannot be other than objectionable. The electro-motor will replace this gearing in the near future, and so it will go on and eventually replace the steam apparatus itself. I do not think I can be rightly accused of speaking merely as an enthusiast, but may fairly claim to understand some of the conditions which obtain in ship life, and I feel warranted in expressing my own confidence that the future will solve every difficulty which the application of electricity to classes of motive power I have mentioned on board ship may demand. One of the great advantages in the use of electricity on board ship is the ease with which the conductors may be handled and run as compared with steam pipes, and also the facility with which they can be replaced in case of accident. The generating apparatus can be placed well out of the range of shot and shell, and easily protected. Another field for electric motors on

board ship is in making repairs. To-day, if a drill is to be operated, a new bolt hole made, or any other work requiring tools of this character, they must be operated by a slow, tedious handgear; whereas a portable motor, with its flexible shaft and brace, can be introduced in the most out of the way part of boilers and engines, and work there performed which, were it done in the ordinary method, would require extensive preparations involving, possibly, the removal of heavy parts of machinery. Torpedoes can be operated as well as controlled by electricity. Diving operations and repairs to the ship's skin under water and in dock, repairs to armor, turrets, and to gun carriages can all be facilitated by the use of electric motors.

The methods of making these various applications of electric power may well receive the careful thought and criticism of all officers who desire the best good of the service, and I have no doubt but that many most valuable suggestions will in the future come from those who to-day look with conservative doubt upon the practicability of these proposals.

## DISCUSSION.

THE CHAIRMAN.—*Gentlemen*:—There is no practical application of electricity that is now attracting more attention or is of greater importance than the transmission of power by electricity. The telephone may be greatly improved, but it has taken its place as a successful invention and an indispensable instrument in conducting the ordinary affairs of life. It is not improbable that in a few years the electric motor will be made more useful than the telephone.

The science of electricity is so far advanced that no ignorant man will by accident hit upon a successful motor. Such a motor must be constructed in strict accordance with scientific principles. To be successful in these days of close competition it must be more than almost correct—it must be exactly right. It will be the result of the thoughtful work and experiment of an ingenious man well trained in modern science.

We are very fortunate in having had the opportunity to listen to one so thoroughly competent, so ingenious, so enthusiastic, and so successful as the lecturer of this evening.

The Naval Academy is to be congratulated that one of its graduates is in a position to return and, in this building, where he received his first theoretical and practical training in physical science, speak with authority as one of the foremost inventors and investigators in this branch of electrical science.

The subject is now before the Institute for general discussion. Mr. Sprague will, I doubt not, be happy to answer any questions that members of the Institute may wish to ask.

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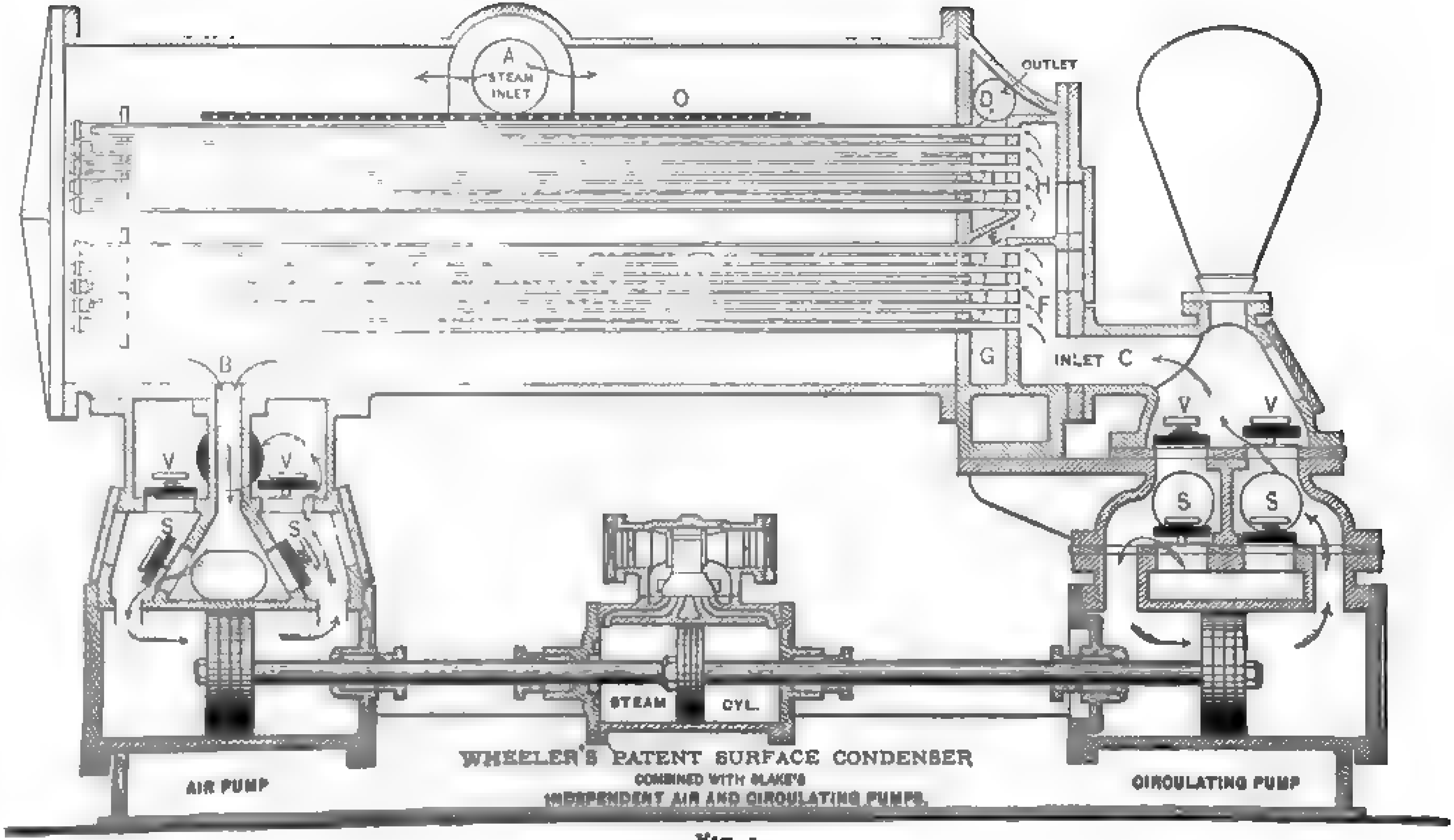
After some discussion of the feasibility of transmitting power over great distances, and of methods for testing the efficiency of motors, a vote of thanks, on the motion of Commander P. F. Harrington, was extended to Mr. Sprague for his valuable and instructive paper. The meeting then adjourned.


A
STEAM INLET
O
OUTLET
D
H
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INLET C
B
V
S
STEAM
CYL.
WHEELER'S PATENT SURFACE CONDENSER
COMBINED WITH BLAKE'S
INDEPENDENT AIR AND CIRCULATING PUMPS.
AIR PUMP
CIRCULATING PUMP

Fig. 1.

# PROFESSIONAL NOTES.



## THE WHEELER SURFACE CONDENSER.

By W. F. Worthington, P. A. Engineer, U. S. N.

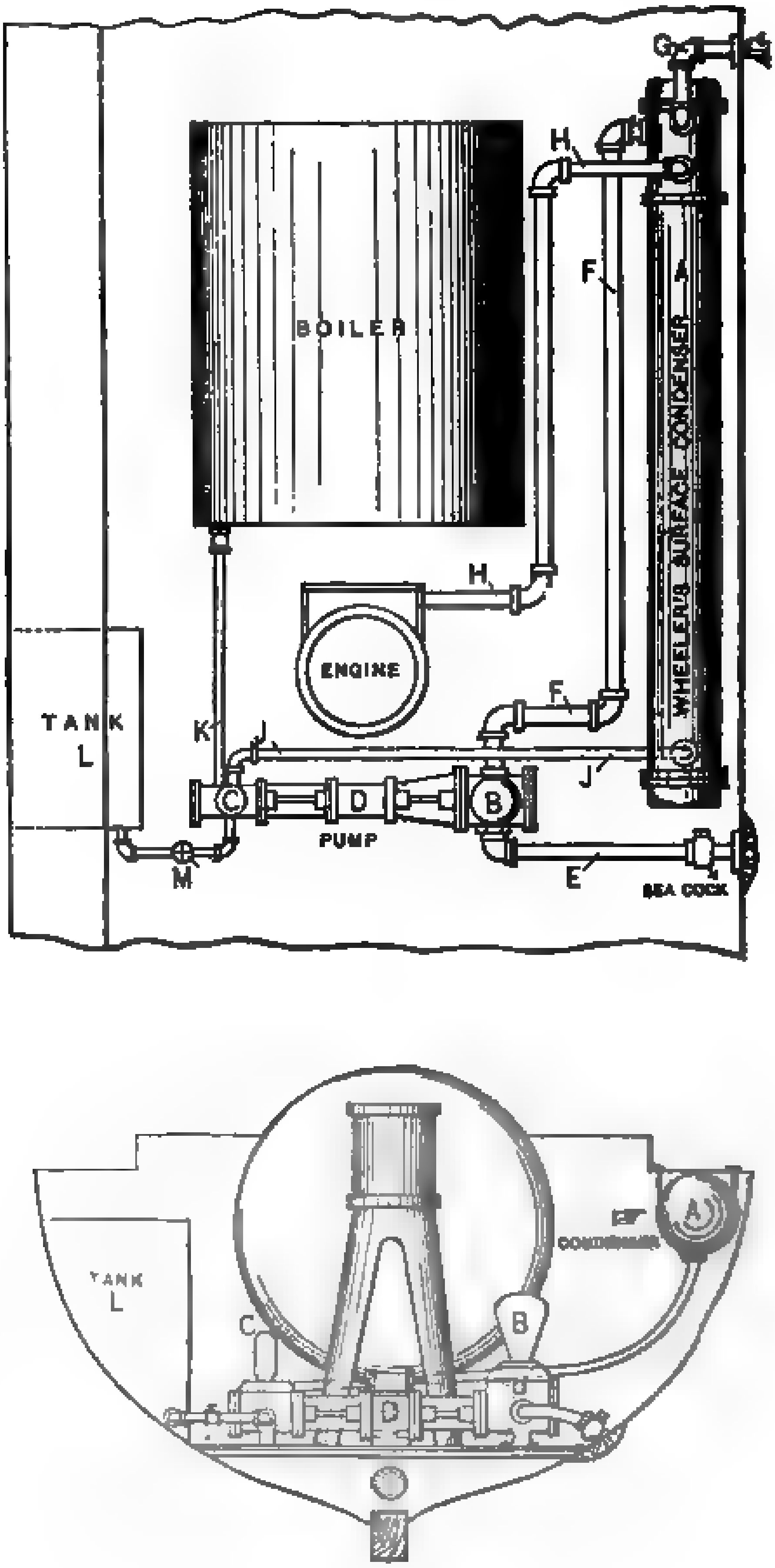
This condenser (Fig. 1) is similar to that patented by Mr. Loftus Perkins and described by him in a paper* read before the Institute of Mechanical Engineers in England.

The principal feature is the arrangement of one tube within the other, the circulating water passing through the inner tube and returning through the space between the tubes. It is readily seen, by inspection of the figure, that with this system the weight of the tubes and contained water will be slightly greater per square foot of cooling surface than it is with the ordinary arrangement of the tubes, and the weight of the remainder of the condenser about the same. The advantages to be expected are: first, increased efficiency of the tube surface; second, decreased work to be done by the circulating pump. With regard to the first advantage, extensive experiments were made by Joule† with apparatus similar in arrangement to this condenser, but differing in the unimportant detail that the steam passed inside and the water outside of the condensing tube. The experiment in which the condensing surface was most efficient showed that nearly 32 pounds of dry steam, entering the condenser at 30 pounds pressure, could be condensed per hour per square foot of surface with the injection at 44° F., discharge 90° F., hot well 122° F., and a vacuum of 26 inches maintained. This result is much in excess of those attained with the ordinary form of condenser, in which the tube surface is calculated to condense about 9 pounds of steam per square foot per hour,‡ and 13 pounds per square foot per hour is considered very fair work§ when the injection is 60° F. and feed 120° F. Joule's experiment referred to was made with a clean copper tube, but further experiments showed that the material, whether copper, iron, or lead, and the thickness within reasonable limits, made no practical difference. The principal difficulty in the conduction of heat arose from a film of water adhering to the tube surface, and any means adopted to prevent this largely increased the efficiency. The arrangement adopted by Wheeler is well calculated to compel a circulation at the tube surface and may fairly be expected to give excellent results.

With regard to the second advantage. Joule found that with equal weights of circulating water the weight of water condensed was increased by diminishing the space between the inner and outer tube, and in one case, when the space was decreased from 0.325 inch to 0.06 inch, the weight of condensed steam

* Engineer, London, June 8, 1877.
† Scientific Papers of J. P. Joule, London, 1884.
‡ Die Schiffsmaschine, Busley, Kiel, 1883.
§ Manual of Marine Engineering, Seaton, London, 1883.

Fig. 2.


BOILER
ENGINE
TANK
L
PUMP
SEA COCK
WHEELER'S SURFACE CONDENSER
A
B
C
D
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F
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H
J
K
M
TANK
L
CONDENSER
A
B
C
D

was nearly doubled, while the weight of circulating water remained the same. The increase of the hydraulic head necessary to force the water through the tubes in the second case was very little, so that the saving in work done by the circulating pump with Wheeler's arrangement would probably be considerable. Furthermore, Joule found that by placing between the inner and outer tube, wire coiled in form of a helix to give a rotary motion to the water, the efficiency of the condensing surface was still further increased without materially affecting the hydraulic head required to force the water through the tubes, a fact which goes to show that a large part of the work done by the circulating pump with the ordinary form of condenser is wasted.

Experiments with a small condenser of the Wheeler type* with 4.27 square feet of tube surface showed nearly 102 pounds of steam condensed per square foot per hour, the injection being 56½° F., discharge 98° F., hot well 138° F., vacuum 24½ inches. This is a much better result than any obtained by Joule with the apparatus before mentioned. The difference may be partly accounted for if the steam was very wet, while that in Joule's experiments was known to be quite dry. Also the ratio of length to diameter of the tubes may have been better than in Joule's apparatus, it being well known that the evaporative efficiency of locomotive boilers is considerably affected by slight changes in these proportions.

One of the advantages of the Wheeler condenser is the ease with which the tubes may be removed for cleaning or renewal. An eminent authority† says that facility for cleaning the tubes is the principal point to be considered in designing a condenser.

Another advantage is that the tubes being screwed into the tube sheets and free on one end, there is no trouble from "crawling," and no packing to get leaky if the condenser is unused for a long period, as often occurs with naval vessels, or to be injured by accidental overheating of the condenser or by boiling to clean the tubes.

The body of the condenser shown in the figure for use on land is made of cast iron, but for use on shipboard these condensers are also made of steel, wought iron, or rolled brass plates. The cylindrical form of cross section allows the weight to be reduced to a minimum.

Fig. 2 shows a plan and elevation of the "light-weight" condenser adapted for yachts, launches, etc.

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## COLLISION, OR GROUNDING MAT.

By Commander G. King Hall, R. N.

[*Reprinted from Journal of the Royal United Service Institution.*]

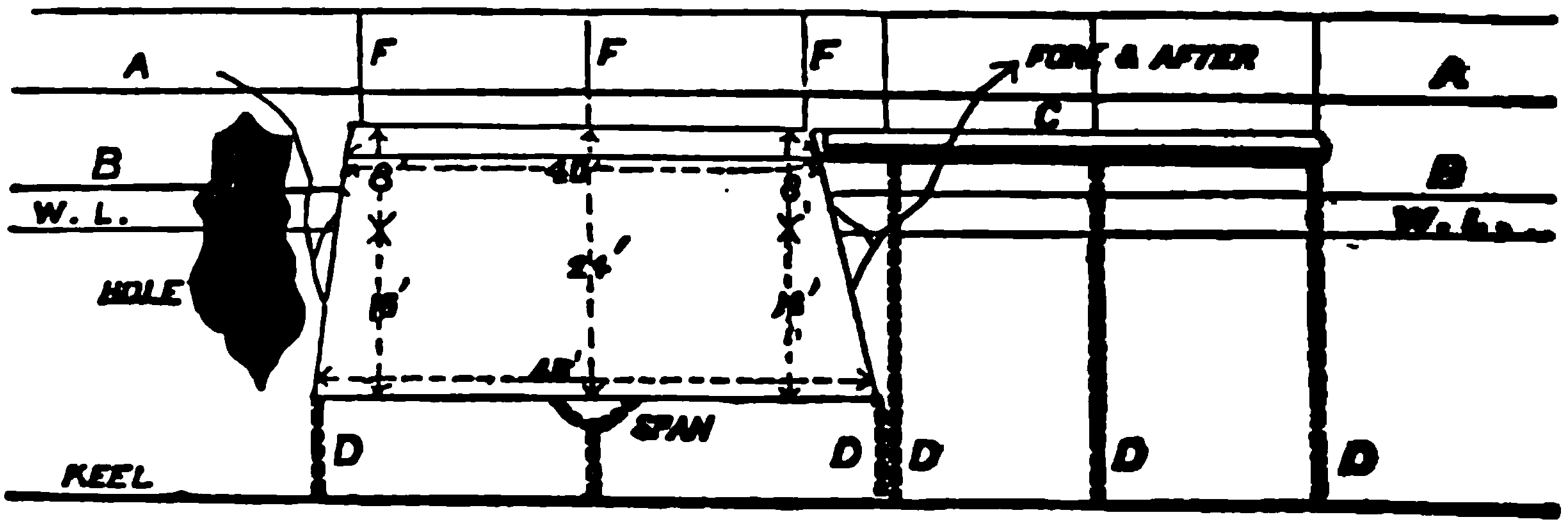
As an officer who has served some years as First Lieutenant and Commander, I am convinced that the present collision mat, 12′ by 12′, is of little practical use, and those who know the difficulty of placing these mats and the time required—not to getting it over for drill purposes, but of accurately placing it—will agree with me that if a ship be rammed, and a serious hole made in her, by the time the mat was placed she would be full of water.

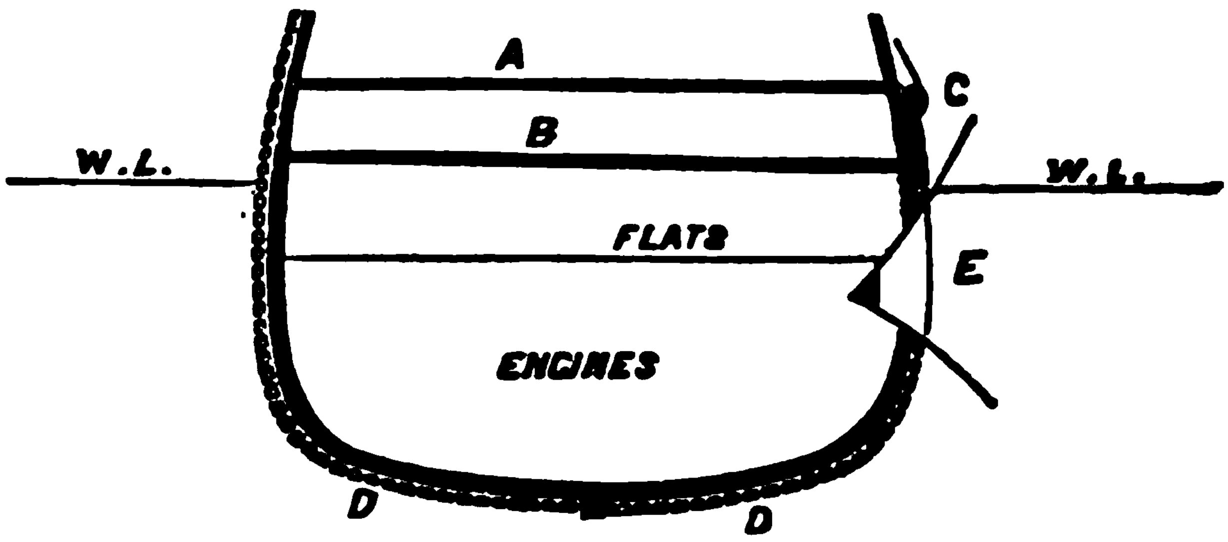
I would propose that mats of double No. I canvas should be, when at sea (if considered advisable, in harbor), kept permanently rolled and stopped up on the outside of ship ready for immediate use.

* American Machinist, May 15, 1886.
† Modern Marine Engineering, Burgh, London, 1867.

SHANNON.

(Abreast engine room.)




*A* Upper Deck. *C* Mat rolled up. *E* Ram of Shannon.
*B* Main Deck. *D D* Bottom chains. *F F* Tricing lines.

Scale $\frac{1}{32}''$ to a foot.

DIMENSIONS OF MAT.

*Head*, 40 feet long, and has a wire jackstay secured to bolts in ship's side, about 8 feet above water line.

*Depth of Mat*, about 24 feet, giving about 16 feet under water, the leach having a short fore and after in it, and end kept out when mat is rolled up, ready for immediate use.

*Foot*, 46 feet (so that the mats should overlap if by any chance the ship was rammed exactly between two mats); and to the foot are attached two iron round bars, 2 inches in diameter (each weighing about 230 pounds) and 23 feet long.

*Bottom chains*, going from each end of mat and one from the centre, connected by wire or chain span to the two inner ends of bars, consequently each mat would have three bottom lines.

Brails or tricing lines for tricing up foot when required.

In most of our large ships, four of these mats a side would be sufficient (in some of our smaller ironclads, such as the Shannon, three would be ample); four of these mats would cover a space of 160 feet, where the large compartments of ship are, as both forward and aft ships are so much protected by cellular compartments and also by the "run" of ship.

These mats should be always kept on at sea, especially when expecting an engagement; and if in an action the ship were rammed, or a hole made by a Whitehead torpedo, all that would be required would be to cut the straps (or,

if fitted with tumblers, slip the foot), and the mat would then fall into its place, and steady taut the bottom lines; this could be done in two minutes; no bother in the middle of an action about whips, bottom lines, fore and afters, all to be bent on and perhaps foul, in the excitement of moment and difficulty of placing mat under fire.

If ship grounded and a large hole were made more than 16 feet under water, the head of mat can be at once cleared away and mat lowered and hauled over hole.

N. B.—These dimensions are only approximate, and might, on trial, require some slight modifications.

I believe if Vanguard had possessed these mats she would have been saved from sinking.

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# REPORT ON THE PERMISSIBLE LIMITS OF ELECTRICAL RESISTANCE OF SERVICE FUZES AND DETONATORS.

TORPEDO STATION, NEWPORT, R. I.,
*March* 5, 1887.

*Sir:*—In fixing the limits of electrical resistance for fuze bridges, the service for which they are intended and the firing apparatus to be used with them must be taken into consideration.

The ordinary uses to which electrical fuzes, detonators and cannon primers are put in the service at the present time, are the firing of a single torpedo from a boat, one to four torpedoes from a ship or a broadside battery. Ten may be considered as the maximum number of guns in the broadside of any ship in our service, and the introduction of high-powered guns will probably decrease this number.

The firing apparatus issued to the service are the Farmer's dynamo machines, pattern A and C, and the ship's and boat's firing batteries of six and four M. C. L. cells respectively.

As some vessels are furnished with a boat's outfit only, the A machine and ship's firing battery are not always found on board. The boat's battery is more especially designed to fire a single torpedo from a boat, and as it polarizes rapidly on being used it is not suitable for experimental purposes. It was therefore decided that a fuze bridge of such resistance that ten of them arranged in series might be rapidly and quickly fired by the C machine would best answer the requirements of the service. On this basis the experiments were conducted.

Farmer's C machine having an average electro-motive force of eight volts and an internal resistance of four ohms, has generally been considered as capable of firing from eight to ten fuzes of standard resistance (.62 ohm to .68 ohm, both inclusive) arranged in series, or a single fuze through 1500 feet of Siemens cable such as now used in the service. Using the standard bridge of iridin-platinum wire (90 per cent platinum, 10 per cent iridium) $\frac{3}{16}$ inch long and .002 inch diameter, a current of .6 ampere, which gives a hot resistance of 1.15 ohms to bridge, is necessary to instantly fire gun-cotton, which is used as priming. Neglecting the resistance of leading wires, the C machine is found theoretically capable of firing eight standard fuzes arranged in series. It may be stated that a less current, as, for instance, .5 ampere, is sufficient to fire gun-cotton, but requires a sensible time.

During the experiments it was found that the C machine would practically fire ten fuzes of standard resistance arranged in series, at apparently the same instant. In twelve experiments of this nature, whether the bridges were made up into igniters or simply primed with gun-cotton, there were no failures. When a bridge of .59 ohm resistance or less was introduced into the series

therewere frequent failures, though as a rule when the resistance did not vary much from the standard all the bridges fired. The same may be said of bridges having a resistance greater than standard.

We have not been able to explain the cause of failure in any special case, but a general explanation may be given as follows. In the manufacture of bridges of any standard resistance, variations in resistance may be due to—

1st. Errors in measurement of length of bridge.

2d. Difference in amount of solder used to fastened ends of bridge.

3d. Solder or foreign material adhering to the bridge at the middle or near the ends.

4th. Errors in measurement of bridge resistance due to differences in temperature and humidity of atmosphere.

These errors are to a certain extent unavoidable, but are reduced to a minimum when an experienced workman is employed in the manufacture of the fuzes. It will be seen from the above that a bridge of a certain length may have the same resistance as a longer one having a greater amount of solder at its ends, or solder or foreign material at its middle or near the ends. Also that a bridge having a certain resistance at the time of measurement may have greater or less resistance when required for firing. Bridges having the same resistance but differing in accuracy of construction may, therefore, require different conditions for firing, and bridges of exactly the same construction, measured at different times, may have different resistances. Moreover, in any experiments where a dynamo machine is used, differences in electro-motive force must occur, owing to the variations in turning the crank. Like variations in electro-motive force will occur in the use of a battery which is not constant.

Far better results were obtained when the bridges were simply primed than when made up into igniters. This is explained as follows: When igniters are used, the bridges which are first raised to the required temperature are broken by the explosion of the igniters, thus preventing the others from firing through delayed action. When simply primed with gun-cotton the bridges are seldom burned off, and a continuous turning of the crank of the machine is only necessary to fire all.

As a result of our experiments we are of the opinion that bridges of the wire now in use having an electrical resistance of not more than .70 ohm nor less than .60 ohm are best adapted to the requirements of the service. A somewhat smaller limit should be adopted as an element of safety, because errors are likely to occur in the measurement of resistance from the causes heretofore stated, and because certainty of action is the most important consideration in torpedo practice. The present standard bridge appears to answer all the requirements, and, if the fuzes be properly made by an experienced workman, little or no waste will result from its adoption.

To conclude, we are of the opinion that the present standard bridge, having an electrical resistance of .62 to .68 ohm, both inclusive, is the best, both theoretically and practically, and do therefore recommend that its use in the service be continued.

LIEUTENANT J. A. SHEARMAN, U. S. N.
ENSIGN G. W. DENFELD, U. S. N., *Recorder.*

COMMANDER C. F. GOODRICH, U. S. N.,
*Inspector in Charge.*

The following is a list of the experiments upon which the above report is based. In each case ten igniters or bridges were connected in series and joined to the C machine by short leading wires.

The tables are arranged in five columns:

The 1st showing the experiment number.

2d, the resistance of the bridge.

3d, the number of igniters or bridges used of resistance shown in the 2d column.

4th, the place of each bridge in the circuit numbered from the positive wire.

5th, the results.

| Experiment No. | Resistance. | No. in Series. Igniters. | No. in Series. Bridges. | Place in Circuit. | | Results. |
|---|---|---|---|---|---|---|
| 1 | .62 | 1 | | 10 | | Fired. |
| | .64 | 5 | | 1, 2, 3, 4, 5 | | " |
| | .65 | 1 | | 9 | | " |
| | .66 | 2 | | 6, 7 | | " |
| | .68 | 1 | | 8 | | " |
| 2 | .62 | | 2 | 9, 10 | | " |
| | .63 | | 1 | 4 | | " |
| | .64 | | 1 | 5 | | " |
| | .65 | | 2 | 1, 3 | | " |
| | .66 | | 2 | 2, 6 | | " |
| | .67 | | 1 | 7 | | " |
| | .68 | | 1 | 8 | | " |
| 3 | .62 | | 1 | 6 | | " |
| | .63 | | 2 | 1, 5 | | |
| | .64 | | 1 | 9 | | |
| | .65 | | 2 | 2, 8 | | |
| | .66 | | 1 | 7 | | |
| | .67 | | 2 | 3, 4 | | |
| | .68 | | 1 | 10 | | |
| 4 | .62 | | 2 | 2, 4 | | Fired. |
| | .64 | | 2 | 1, 5 | | " |
| | .65 | | 3 | 6, 9, 10 | | " |
| | .67 | | 2 | 3, 8 | | " |
| | .68 | | 1 | 7 | | " |
| 5 | .62 | | 2 | 1, 2 | 9, 10 | " |
| | .63 | | 1 | 3 | 8 | " |
| | .64 | | 1 | 4 | 7 | " |
| | .65 | | 2 | 5, 6 | 5, 6 | " |
| | .66 | | 1 | 7 | 4 | " |
| | .67 | | 2 | 8, 9 | 2, 3 | " |
| | .68 | | 1 | 10 | 1 | " |
| 6 | .62 | | 2 | 1, 2 | 9, 10 | " |
| | .63 | | 1 | 3 | 8 | " |
| | .64 | | 1 | 4 | 7 | " |
| | .65 | | 2 | 5, 6 | 5, 6 | " |
| | .66 | | 1 | 7 | 4 | " |
| | .67 | | 2 | 8, 9 | 2, 3 | " |
| | .68 | | 1 | 10 | 1 | " |
| 7 | .62 | | 4 | 2, 7, 8, 10 | 1, 3, 4, 9 | " |
| | .63 | | 2 | 4, 6 | 4, 5 | " |
| | .65 | | 1 | 5 | 6 | " |
| | .66 | | 1 | 9 | 2 | " |
| | .67 | | 2 | 1, 3 | 8, 10 | " |

| Experiment No. | Resistance. | No. in Series. Igniters. | No. in Series. Bridges. | Place in Circuit. | | Results. |
|---|---|---|---|---|---|---|
| 8 | .62 | | 2 | 6, 8 | 3, 5 | Fired. |
| | .64 | | 1 | 1 | 10 | " |
| | .65 | | 3 | 4, 5, 10 | 1, 6, 7 | " |
| | .66 | | 2 | 3, 9 | 2, 8 | " |
| | .67 | | 2 | 2, 7 | 4, 9 | " |
| 9 | .63 | | 2 | 3, 10 | 1, 8 | " |
| | .64 | | 3 | 4, 7, 9 | 2, 4, 7 | " |
| | .66 | | 1 | 6 | 5 | " |
| | .67 | | 3 | 1, 5, 8 | 3, 6, 10 | " |
| | .68 | | 1 | 2 | 9 | " |
| 10 | .62 | | 9 | 1, 2, 3, 4, 6, 7, 8, 9, 10 | | " |
| | .63 | | 1 | 5 | | " |
| 11 | .64 | | 2 | 1, 2 | 9, 10 | " |
| | .65 | | 4 | 7, 8, 9, 10 | 1, 2, 3, 4 | " |
| | .66 | | 4 | 3, 4, 5, 6 | 5, 6, 7, 8 | " |
| 12 | .67 | | 5 | 1, 4, 5, 7, 9 | | " |
| | .68 | | 5 | 2, 3, 6, 8, 10 | | " |
| 13 | .61 | 1 | | 10 | | " |
| | .63 | 1 | | 1 | | " |
| | .64 | 3 | | 2, 3, 4 | | " |
| | .65 | 5 | | 5, 6, 7, 8, 9 | | " |
| 14 | .60 | 1 | | 1 | | " |
| | .63 | 1 | | 2 | | " |
| | .64 | 3 | | 3, 4, 5 | | " |
| | .65 | 5 | | 6, 7, 8, 9, 10 | | " |
| 15 | .60 | 1 | | 1 | | " |
| | .63 | 1 | | 2 | | " |
| | .64 | 3 | | 3, 4, 5 | | " |
| | .65 | 5 | | 6, 7, 8, 9, 10 | | " |
| 16 | .59 | 1 | | 1 | | Failed. Afterwards was fired by itself. |
| | .63 | 1 | | 2 | | Fired. |
| | .64 | 3 | | 3, 4, 5 | | " |
| | .65 | 5 | | 6, 7, 8, 9, 10 | | " |
| 17 | .57 | 1 | | 1 | | " |
| | .63 | 1 | | 2 | | Failed. Afterwards was fired by itself. |
| | .64 | 3 | | 3, 4, 5 | | Fired. |
| | .65 | 5 | | 6, 7, 8, 9, 10 | | " |
| 18 | .39 | 1 | | 1 | | " |

| Experiment No. | Resistance. | No. in Series. Igniters. | No. in Series. Bridges. | Place in Circuit. | Results. |
|---|---|---|---|---|---|
| 18 | .62 | 2 | | 2, 3 | Fired. |
| | .63 | 5 | | 4, 5, 6, 7, 8 | “ |
| | .64 | 2 | | 9, 10 | “ |
| 19 | .27 | 1 | | 10 | Failed. Afterwards was fired by itself. |
| | .63 | 1 | | 1 | Fired. |
| | .64 | 3 | | 2, 3, 4 | “ |
| | .65 | 5 | | 5, 6, 7, 8, 9 | “ |
| 20 | .64 | 2 | | 1, 2 | |
| | .65 | 5 | | 3, 4, 5, 6, 7 | |
| | .66 | 2 | | 8, 9 | |
| | .77 | 1 | | 10 | |
| 21 | .63 | 1 | | 1 | Fired. |
| | .64 | 3 | | 2, 3, 4 | “ |
| | .65 | 2 | | 5, 6 | “ |
| | .66 | 3 | | 7, 8, 9 | No. 9 failed. Afterwards fired singly. |
| | .77 | 1 | | 10 | Fired. |
| 22 | .62 | | 2 | 6, 8     3, 5 | “ |
| | .65 | | 3 | 4, 5, 10     1, 6, 7 | “ |
| | .66 | | 2 | 3, 9     2, 8 | “ |
| | .67 | | 2 | 2, 7     4, 9 | “ |
| | .77 | | 1 | 1     10 | “ |
| 23 | .63 | 1 | | 2 | “ |
| | .64 | 3 | | 3, 4, 5 | “ |
| | .65 | 5 | | 6, 7, 8, 9, 10 | “ |
| | .79 | 1 | | 1 | “ |
| 24 | .61 | | 1 | 10 | “ |
| | .62 | | 1 | 9 | “ |
| | .63 | | 1 | 8 | “ |
| | .64 | | 1 | 6 | “ |
| | .65 | | 1 | 3 | “ |
| | .66 | | 2 | 1, 4 | “ |
| | .67 | | 1 | 2 | “ |
| | .68 | | 1 | 5 | “ |
| | .69 | | 1 | 7 | “ |
| 25 | .60 | | 1 | 8 | “ |
| | .61 | | 1 | 7 | “ |
| | .62 | | 1 | 6 | “ |
| | .63 | | 1 | 10 | “ |
| | .64 | | 1 | 5 | “ |
| | .66 | | 1 | 9 | “ |
| | .67 | | 1 | 3 | “ |
| | .68 | | 1 | 1 | “ |

| Experiment No. | [illegible] | No. of [illegible] Igniters | No. of [illegible] Bridges | Place in Circuit | Results. |
|---|---|---|---|---|---|
| [illegible] | [illegible] | | [illegible] | 4 | Fired. |
| | [illegible] | | [illegible] | 2 | " |
| 26 | .60 | | 1 | 2 | " |
| | [illegible] | | 1 | 3 | " |
| | .61 | | 1 | 5 | " |
| | .62 | | 1 | 4 | " |
| | .63 | | 1 | 10 | " |
| | [illegible] | | 1 | 1 | " |
| | .68 | | 1 | 6 | " |
| | .69 | | 1 | 7 | " |
| | .70 | | 1 | 8 | " |
| | .71 | | 1 | 9 | " |
| 27 | .50 | | 1 | 8 | " |
| | .60 | | 1 | 9 | " |
| | .61 | | 1 | 6 | " |
| | .62 | | 1 | 7 | " |
| | .63 | | 1 | 1 | " |
| | [illegible] | | 1 | 10 | " |
| | .68 | | 1 | 2 | " |
| | .69 | | 1 | 3 | " |
| | .70 | | 1 | 4 | " |
| | .71 | | 1 | 5 | " |
| 28 | .61 | 3 | | 1, 2, 3 | " |
| | .62 | [illegible] | | 4, 5, 6, 7, 8, 9, 10 | " |
| 29 | .57 | | 1 | 5 | " |
| | .62 | | 2 | 9, 10 | " |
| | .63 | | 1 | 4 | " |
| | .65 | | 1 | 3 | " |
| | .66 | | 1 | 2 | " |
| | .67 | | 1 | 7 | " |
| | .68 | | 1 | 8 | " |
| | .70 | | 1 | 6 | " |
| | .80 | | 1 | 1 | " |
| 30 | .50 | | 1 | 1 | " |
| | .61 | | 1 | 2 | " |
| | .62 | | 1 | 3 | " |
| | .63 | | 1 | 4 | " |
| | .65 | | 1 | 5 | " |
| | .66 | | 2 | 6, 7 | " |
| | .68 | | 1 | 8 | " |
| | .69 | | 1 | 9 | " |
| | | | 1 | 10 | " |
| | | | 1 | 1 | " |

| Experiment No. | Resistance. | No. in Series. Igniters. | Bridges. | Place in Circuit. | Results. |
|---|---|---|---|---|---|
| 31 | .61 | | 1 | 2 | Fired. |
| | .62 | | 1 | 3 | " |
| | .63 | | 1 | 4 | " |
| | .65 | | 1 | 5 | " |
| | .66 | | 1 | 6 | " |
| | .67 | | 1 | 7 | " |
| | .68 | | 1 | 8 | " |
| | .69 | | 1 | 9 | " |
| | .80 | | 1 | 10 | " |
| 32 | .41 | | 1 | 1 | No. 1 failed to fire, but fired singly. |
| | .61 | | 1 | 2 | Fired. |
| | .62 | | 1 | 3 | " |
| | .63 | | 1 | 4 | " |
| | .65 | | 1 | 5 | " |
| | .66 | | 1 | 6 | " |
| | .67 | | 1 | 7 | " |
| | .68 | | 1 | 8 | " |
| | .69 | | 1 | 9 | " |
| | .94 | | 1 | 10 | " |
| 33 | .57 | | 1 | 5 | " |
| | .61 | | 1 | 2 | " |
| | .62 | | 1 | 10 | " |
| | .63 | | 1 | 4 | " |
| | .65 | | 1 | 3 | " |
| | .67 | | 1 | 7 | " |
| | .68 | | 1 | 8 | " |
| | .69 | | 1 | 9 | No. 8 failed. Afterwards fired, connected up in same series by turning crank of machine rapidly. |
| | .70 | | 1 | 6 | |
| | .80 | | 1 | 1 | |
| 34 | .64 | 2 | | 1, 2 | Fired. |
| | .66 | 1 | | 3 | " |
| | .68 | 1 | | 4 | " |
| | .69 | 4 | | 5, 6, 7, 8 | " |
| | .70 | 1 | | 9 | " |
| | .71 | 1 | | 10 | " |
| 35 | .50 | 1 | | 1 | " |
| | .53 | 2 | | 2, 3 | " |
| | .55 | 1 | | 4 | " |
| | .56 | 1 | | 5 | " |
| | .59 | 1 | | 6 | " |
| | .62 | 3 | | 7, 8, 9 | " |
| | .64 | 1 | | 10 | " |
| 36 | .55 | | 5 | 1, 2, 3, 4, 5 | Fired—also when reversed. |
| | .75 | | 3 | 6, 7, 8 | |

| Experiment No. | Resistance. | No. in Series. Igniters. | No. in Series. Bridges. | Place in Circuit. | Results. |
|---|---|---|---|---|---|
| 36 | .70 | | 2 | 9, 10 | |
| 37 | .55 | | 1 | 1 | Fired—also when reversed. |
| | .56 | | 1 | 2 | |
| | .57 | | 1 | 3 | |
| | .58 | | 1 | 4 | |
| | .59 | | 1 | 5 | |
| | .71 | | 1 | 6 | |
| | .72 | | 1 | 7 | |
| | .73 | | 1 | 8 | |
| | .74 | | 1 | 9 | |
| | .75 | | 1 | 10 | |
| 38 | .55 | | 1 | 3 | Fired—also when reversed. |
| | .56 | | 1 | 2 | |
| | .57 | | 1 | 10 | |
| | .58 | | 1 | 7 | |
| | .61 | | 1 | 1 | |
| | .69 | | 1 | 5 | |
| | .70 | | 1 | 8 | |
| | .72 | | 1 | 4 | |
| | .74 | | 1 | 9 | |
| | .75 | | 1 | 2 | |
| 39 | .57 | | 1 | 1 10 | Fired. |
| | .58 | | 1 | 2 9 | " |
| | .59 | | 1 | 3 8 | " |
| | .60 | | 2 | 4, 5 6, 7 | " |
| | .61 | | 5 | 6, 7, 8, 9, 10 1, 2, 3, 4, 5 | " |
| 40 | .74 | | 3 | 1, 2, 3 | Fired—also when reversed. |
| | .75 | | 3 | 4, 5, 6 | |
| | .76 | | 4 | 7, 8, 9, 10 | |

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# PNEUMATIC WATER ELEVATING APPARATUS FOR SUPPLYING SHIPS WITH WATER.

(Invented by ARMISTEAD RUST, Naval Cadet, U. S. N.)

The apparatus consists of a series of tanks in the after hold for containing hot and cold fresh water and the waste water from the bath-tubs and basins of a ship. After a tank is filled with water it is put in connection with a receiver filled with air of sufficient pressure to cause the water to flow up to the basins, rboard when the proper cocks are opened. The air is compressed by a

pump worked by an eccentric on the main engine shaft, or preferably by a separate engine.

The water in the hot-water tank is heated by a few turns of a steam pipe. It is proposed to use the waste water in case of fire by shutting the outboard connection and attaching a hose to a nozzle provided. Suitable gauges and safety valves are fitted to the tanks. W. F. W.

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# THE TACTICS OF INFANTRY IN BATTLE.

By Colonel Sir Lumley Graham.

[*Reviewed by Lieut. D. H. Mahan, U. S. N.*]

This interesting pamphlet, reprinted at the U. S. Artillery School, Fortress Monroe, contains a great deal of valuable information. It is well known that neither our Army nor Navy possesses any work on modern tactics. Regiments and brigades are still drilled according to Upton. The deployments and skirmishings as taught are much behind the present system of foreign tactics, and it is necessary that some step should be taken to remedy this state of affairs, to so change our tactics as to make them in some manner similar to those adopted by the military nations, France, Germany, and Austria.

Let us look at some of the general principles adopted by these three nations and see if they will not give food for thought to many of us.

"1. The relative value of the firearms (cannon and musket) and of the side arms (sword and bayonet) has been much affected by modern technical improvements. The firearm is now undoubted mistress of the battle-field, where everything is subordinate to it.

2. The formation of infantry for battle must be such as to favor to the utmost the effect of its own fire, and to minimize the damage done by that of the enemy. Within effective ranges everything must give way to these two considerations.

3. For the front or "firing line" the only formation, both in attack and defense, which meets these requirements, is a line of small sections extended in single rank (which are called a line of skirmishers), which from being at first very open becomes more and more dense as the antagonists come to close quarters, attaining at last almost the consistency of a line in close order.

4. This "firing line" has a very different mission to that of the old "line of skirmishers." The latter had only to prepare the way for the columns or lines and to supplement their efforts; the former, on the contrary, has to fight the battle out through all its stages to the very conclusion, being supported in doing so by the troops in close order.

7. A tactical body once thrown into a firing line on the offensive cannot be relieved; its remnants, great or small, will remain in the firing line to the end of the action.

8. The comparatively loose formations necessary in the present day render supervision and control on the part of superiors more difficult. Tactical dispositions will again do something to remedy this evil, but *thorough discipline and training will do more*, contributing, as they will, to the complete maintenance of the chain of responsibility, from the Commander-in-chief right down to the leader of the smallest squad in the fighting line.

9. The importance of the company as a battle unit is much increased, and *pari passu* the importance of the Captain as a commander.

13. The tactical desiderata for an ideal defensive position are: First and foremost, a clear field for fire, both to the front and flanks, for some three thousand yards; secondly, ground sloping gently downwards towards the

enemy; thirdly, well-secured flanks, and no prominent salient angles; fourthly, good cover for supports and reserves at a convenient distance from the fighting line; fifthly, good sheltered communications from the rear and along the position; sixthly, good positions for batteries in rear and on higher ground than infantry.

15. Good infantry need not fear the attack of cavalry, even if in extended order. As a general rule they should be able to maintain the formation in which they happen to be when threatened. To do otherwise will be only to play the enemy's game.

19. A mere passive defense will produce no great result. A commander when on the defensive must always be prepared to make a counter-attack at the right moment."

These selections teach us to undo much we have been taught to do. They bring to our notice that the ideas we still hold to in instruction are of but little use in action, and that the company commander now is the one on whom much of the onus of the fight will fall. The responsibility does not now rest with one or two men, but with all, from the Commander-in-chief to the private, and the responsibility being so much more divided, the instruction must be so much more extended and perfected.

The tactical desiderata give us the ideas we want; continual practice must be had to enable one to take advantage of the ideas taught. The styles of firing have changed so much now that the instruction must be changed and the soldier or sailor made almost an expert with the rifle, and especially with the repeating rifle. The instructions given must be with a view to a careful nursing of supply until the critical moment, the efficiency of group firing and the supreme importance of entire attention to orders given by the company officers.

The last but by no means the least important article (19) shows how very important it is for the Commander-in-chief of the force to be one capable of seizing upon any and every opportunity that chance or bad management on the opposing side may offer to him by which some advantage may be gained. It shows that a careful selection should be made in giving command of an expedition, not giving it to rank, but to the one known to be the best military commander.

From page 5 to 8 the details of infantry fighting are dwelt upon, considering the distribution of a battalion acting by itself on the offensive. In these pages the divisions of the company are given (each nation having a paragraph to itself), and its actions as the "advanced company in the first stage of the fight." Also "the rest of the battalion during the first stage." Page 8 commences the second stage of the fight, which supposes the attacking force to be about 500 yards from the enemy's position. "Put off the moment of opening fire as long as you can, and get as near the enemy's position as possible before doing so," is the German idea. The French say at 650 yards fire should be opened along the whole line, while Austria leans more to the German idea and only admits of general firing at 300 paces. The kind of fire employed by Germany is either volleys (those of the line or groups), individual (or skirmishing) fire, and rapid independent fire, but it is insisted that from the moment fire is opened it should become general, because the object of the assailant is to subdue the defender's fire so as to facilitate his own advance. France only allows rapid independent fire with the 200-metre sight. Austria, while recognizing only one sort of fire when in extended order, that of individual firing, yet, in the case of men in close order, admits of volleys and of independent firing. Pages 11 and 12 are devoted to gaining ground under fire; page 13 to supports and reserves under fire, and to the assault. The storming distance as considered by Germany is not less than 200 yards on open ground, and we would quote these words: "The maximum distance to be traversed in the final charge must depend upon the physical powers of the assailants, as there must be no check. This rush [illegible] in one inning. The maximum distance must therefore greatly depend [illegible]her the ground is flat or whether there is a steep gradient, again,

whether the soil be at the time light or heavy." The French say the assault should commence at the point beyond which the assailant can make no further progress by the effect of his firearms alone. Austria considers 80 to 100 paces as the maximum distance to be traversed when storming. "By whom will the order for the charge be given?" Germany gives it to the leaders of the foremost bodies. France gives it to no specified person, but seemingly to the battalion commander. Austria allows it to the leaders of the fighting line. The execution of the assault and after the assault are referred to on pages 14 and 15, and this rule is held to by all: "Infantry not to pursue the retreating enemy, but only to fire after them. If woods or villages are carried, their further borders should be occupied at once. The interior should be well searched by a portion of the reserve, which should at once rush up to the position, the remainder joining in the fire on the retreating enemy."

Pages 16 to 21 are given to the "single battalion on the defensive," and on page 17 we find these words: "A commanding officer has thus to provide a sufficiently strong fighting line; next, to feed and reinforce it at need; thirdly, to keep in hand a general reserve; fourthly, to set apart a special body to execute the counter-attack when the proper time comes; and, lastly, to make his tactical dispositions in such a manner as to prevent as far as possible, or, at any rate, to delay to the utmost any intermixture of units." "A defensive action resolves itself into two stages: 1. that of distant fire; 2. that of near fire. The boundary between the two being the moment when the fighting line of the assailants is brought to a standstill and begins to reply effectively to the fire of the defenders." Page 17 also considers the "first stage of the defense." "The object of the defender is to delay the assailant and to make his approach to storming distance as difficult as possible. This must be the work of the rifle, and the question is how best to use it." The Germans tend to volley firing at this stage, first, against deep columns exposing themselves, then, against company columns and lines, lastly, against skirmishers. The French fire, part against skirmishers and the remainder at the supports and reserves. Pages 18 and 19 dwell upon the second stage of the defense, "which reaches its climax when the assailant is preparing to storm. At that moment the defender must bring every disposable rifle into action, except the reserve kept in hand for a counter-attack. Troops brought up at this moment should be in close order; they risk little, for the enemy will be stopping his fire to make his assault, and they will be more under control. This is specially the moment, and one of the few moments, when rapid independent fire is advisable." Page 19 also refers to the counter-attack and further measures. "The necessity of combining the offensive with the defensive, and of not trusting to a mere passive defense, is universally admitted. The question is, When and how is the defender to take the offensive?" Page 20 gives the ideas of the three nations upon this part of the action if the defense is a successful one, or, if unsuccessful, sets forth the different modes of withdrawal. Page 21 sums up a defensive action as follows:

"1. Reconnaissance of the position. Construction of defensive works. Patrols sent out for security.

2. Occupation of the position. As a rule, two companies side by side, each divided into fire-line and supports. The other companies in reserve on one or both flanks.

3. Commence firing volleys at long ranges on marks easily hit. If good opportunities offer, the supports are moved up into the fire-line for short periods.

4. At short ranges independent fire is used. Supports reinforce the firing-line, coming up as a rule by groups.

5. The enemy makes his assault. The defender's reserves move up into line and fire volleys. If possible, a counter-attack upon the flank of the enemy.

6. The defenders pour a heavy fire upon the retiring enemy, or themselves retreat by successive echelons."

This finishes the consideration of the single battalion. A short space is given

to "Infantry against Cavalry," in which all agree that "if attacked by cavalry, infantry should allow itself to be as little disturbed as possible from the formation in which it happens to be. Skirmishers may even receive cavalry without closing if the ground be at all favorable to them. A body of troops in close order had best receive cavalry in line if already deployed or if it have time to do so." Germany has three forms of squares for this defense—battalion, company, and group or rallying squares. France uses company squares, but neither of the others. A battalion in open column forms company-columns and echelons them, or forms line. A battalion in line of company-columns, echelons the companies so that they may support one another. Austria uses rallying squares for skirmishers and company squares for supports, but a battalion attacked by cavalry forms the same as the French. From page 22 to page 28 a battalion forming part of a larger body is considered; on the offensive, (1) battalions in rear line; (2) extent of line; (3) the assault; on the defensive, battalions in rear line. From page 28 to page 37 the question of infantry battle tactics in Russia is considered, and on page 37 is given a comparison between the French and German infantry tactics of the present day, written by an experienced French officer, and which will give to any one interested in tactics for the foot soldier many excellent points. The pamphlet, taken as a whole, is one that should be carefully studied, and it should be in the possession of every one whose duty it may be to have charge of a landing force in either this or any other country. Naval officers can study it to great advantage, for the time is near when we must change our present system to one comprising as principles many of the points laid down in this work.

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## COMBUSTIBLE FOSSILS, REFRACTORY MATERIALS, AND THE IRON INDUSTRY AT THE NATIONAL EXPOSITION OF TURIN IN 1884.

BY L. ADAMI, COLONEL OF ARTILLERY.

(Supplement to the *Rivista d' Artiglieria e Genio*. Translated by W. F. WORTHINGTON, P. A. Engineer, U. S. N.)

Bituminous coal is not found in Italy; the only combustible fossils are anthracite coal and lignite. There are about fifteen localities in Italy where anthracite has been found, but none of them of much commercial importance, as the anthracite is generally of indifferent quality, containing much earthy matter, is in small and distorted veins, and difficult to excavate.

Lignite, on the other hand, is found in abundance and in many localities, and being in some cases of excellent quality, gives rise to an industry of considerable importance. There is one mine, only slightly explored as yet, which contains lignite of such good quality that many scientists consider it bituminous coal. With regard to calorific values, three units of the best lignite are equal to two of ordinary bituminous coal, and of the inferior lignite two units are equal to one of bituminous coal. Besides inferiority in calorific value, some of the lignites have other qualities, such as giving off great volumes of smoke, unpleasant odor, sulphur sufficient to damage fire boxes, also taking fire spontaneously, crumbling and falling through the grate. Many of them produce much clinker which sticks to the grate. The best kinds of lignite are adapted for use in steam boilers for stationary engines, metallurgical, glass, terra-cotta, cement and other furnaces. Other kinds are even better for the same purposes after having been previously artificially dried. The worst kind may be used for the same purposes, but when used to convert pig iron into wrought iron or steel must be burned in a Siemens regenerator or other such furnace. They are not adapted for use in cupolas.

CONGLOMERATES.—The name conglomerate (agglomerato) is given to bricks composed of coal dust mixed with tar (catrame) and subjected to pressure. The bricks are adapted for use in stationary and locomotive boilers and in other industries. Their principal advantages are the small losses which occur in transport, the convenience of handling, and the small space occupied. Their calorific value can never exceed that of the best bituminous coal, and they are necessarily more costly. In Italy this manufacture is very limited, and only introduced to utilize the small quantity of dust from imported coal. The bricks are composed of coal dust and tar (brai-grasso), or of olive seeds (sanze), tar (brai), petroleum residue, schist (scisto), benzine, residual paraffine, stearine and other oleaginous materials. The latter composition, called the Rubino combustible, of which the principal ingredient (80 per cent to 90 per cent) consists of olive seeds, deserves special notice. There are about 500,000 tons of "sanze" produced annually, and the patentee claims that this would furnish enough of his fuel to supply all the requirements of the country both on land and sea. It is to be noted, however, in this connection that the annual importation of bituminous coal is 2,000,000 tons. He claims for the fuel the calorific value of 6800 calories (bituminous coal about 7000—W. F. W.), that it is free from dust, saves the grates, furnaces and boilers, produces no clinker and contains no sulphur, and is 30 per cent to 50 per cent cheaper than other fuels, according to the locality. It should be remembered that much of the "sanze" is now used for fuel in the neighborhood of the oil factories, and if it was all bought up for the manufacture of bricks the price of the latter would rise considerably. Nine varieties of the fuel are produced, each adapted to a special purpose. Experiments made with the fuel in the furnace of a steam-boiler showed 8 kilos of steam at five atmospheres pressure, evaporated per kilo of the fuel, the cost of which latter was about one-half the cost of Cardiff coal. There was no trouble in managing the fire, the fuel did not adhere to the bars or form clinkers, burnt with a beautiful flame and little smoke, was readily lighted, and the bricks burnt regularly and uniformly. The ash was small in quantity, perfectly white, and easily disposed of.

COKE.—As there is no bituminous coal in Italy, the only coke produced is that left from the manufacture of illuminating gas, and is not useful for metallurgical purposes.

TURF.—The scarcity of combustible fossils and the increasing destruction of the forests render even the deposits of turf valuable. The use of this material only dates back about 25 years, but is now quite extensive, even being used in the Siemens regenerative furnace and steam boilers on land and on the lakes. Its calorific value is about the same as that of good lignite, *i. e.* about one-half that of bituminous coal. It occurs almost exclusively in the valley of the Po.

Conclusion.—In the arsenals the native fuels, with the exception perhaps of the Rubino combustible, are not fit to be used in the reverberatory furnaces (forni a riverbero) or in the muffles (forni a manica), but may be used for any other purposes.

REFRACTORY MATERIALS.—Graphite is found in some parts of Italy well adapted for making refractory crucibles, for use as a lubricant for machinery, and mixed with oil forms a varnish for iron. It is used principally, however, for the manufacture of pencils, and is also exported.

FIRE CLAY, FIRE BRICKS, AND CLAY CRUCIBLES.—There is a serious deficiency in good fire clay. Most of the native clays soften at the highest temperature of the iron furnace, and are therefore not well adapted for making fire bricks.

THE IRON INDUSTRY.—Italy is relatively rich in iron ores. Scarcely one-quarter of this is smelted in the country; the remaining three-fourths are exported. The reason for this is the small supply of good native coal and wood charcoal. The native cast iron, however, is of the best quality, and for the manufacture of cast iron guns, that from Lombardy is equal to the best Swedish pig.

[The paper concludes with a short account of the facilities for the manufacture of gun steel and projectiles at the time of the Exposition. Besides the few facts selected for this notice, the paper has full tables of the quantities and qualities of the various materials and the localities in which they are found, and altogether is well worth careful study by both friends and enemies of Italy, the capacity for manufacturing guns and machinery being at the base of a country's military strength.—W. F. W.]

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## AMERICAN STEEL FOR THE NEW CRUISERS.

COMMANDER ROBLEY D. EVANS, U. S. N., Chief Inspector of material for the new cruisers, in conversation with a Washington newspaper correspondent, has made some interesting statements in regard to the quality of steel now being produced by our American manufacturers. As the subject is one of interest to the members of the Institute, we give in full his statements as printed in *The Iron Age* of June 16.

"I think the manufacturers of steel to supply the demands of the Government contracts will agree with me that the system of inspection and the high requirements of the physical properties of the material have done much to promote a higher standard of production than has ever been achieved in the United States. At first the manufacturers looked upon the inspections as unnecessarily severe, but since they have been gathering important lessons by experience they have commenced to realize that it has been to their advantage.

"Let us take the ship plates manufactured by the Park establishment, of Pittsburgh, for the Cramps, of Philadelphia. At first they had great trouble. After weeks of testing and intelligent manipulation the standard was reached, and they are now delivering plates of a better standard than any manufactured abroad. They are up to the best French, and better than the English plates.

"Now let us look at Carnegie, Phipps & Co. They at first experienced the greatest difficulty in the production of ship and boiler material. Now they are delivering the very first quality. I remember the first shoe plate for the cruiser Baltimore. It was 1¾ inches thick and considered an impossibility. After repeated experiments and personal attention I had the pleasure of congratulating the makers not only upon the successful rolling of the plate, but upon the highest and most satisfactory tests. They can now roll any number required without the slightest trouble.

"Now take rivets. The requirements in the specifications were so exacting that several firms declined the contracts. Oliver Brothers & Phillips, who make steel by the Clapp-Griffiths process, finally accepted. At first they met with doubtful success, but after a few weeks' drilling under the eyes of the inspectors they came up to all the requirements. They are now making the rivets right along up to standard. They admit that the Government inspection has not only been an advantage as bringing the steel up to a high standard, but that it has been of advantage to the workmen by teaching them to be careful."

"How about castings?"

"I was about to say that steel castings made under Government contracts surpass everything anticipated. Indeed, so marked has been the success in that direction that Mr. Cramp proposes to use steel castings in parts of ships where it was never used before. The castings for the stern-post and rudder-train and other parts of these vessels have been successfully made by the Standard Steel Casting Company, of Thurlow, and the Midvale Steel Works, of Nicetown, Pa. In fact, results have been achieved far beyond the claims of the most sanguine believers in steel castings.

"This is among the Eastern manufacturers. Now let us turn to the West. It is somewhat remarkable that the Pacific Rolling Mills, of San Francisco, considering the short time they have been in operation, are turning out steel for the California ship which in regularity of physical properties surpasses anything made by Eastern firms. The reports we have of 20 heats, averaging 20 tons to the heat, fall between 60,000 and 62,000 pounds ultimate strength, with an elongation of 28 per cent, 25 per cent being the maximum requirement.

"The steel for the frames and shapes made by the Pennsylvania Steel Company, at Steelton, and rolled by the Phœnix Iron Company, are also beyond what was looked for so soon after the Government work was undertaken.

"With all these practical results it can be said that the Government has done much for metallurgical production in the United States. Better material is being put into the new vessels for the Navy than has ever been put in any ship in the United States, and, as far as the records in our possession show, better than has been put in ships abroad. I think Mr. Cramp and Chief Engineer Melville will agree with me in this."

A record of the results of these inspections is being kept by Lieutenant F. J. Milligan, U. S. N. It will undoubtedly be of great value not only in giving a history of the material used in each ship, but from a scientific point of view.

C. R. M.

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## SYSTEM FOR SIGNALING TO AN APPROACHING VESSEL THE POSITION OF THE HELM.

This system, invented by Captain Staves, and for which he has received a medal at the Liverpool Exposition, and also the thanks of Lloyd and the Board of Trade, consists of two standards placed one on each bow and at such a height as to be clear of the sails. Each standard has at its top a light of the same color as the side light; *i. e.* green to starboard and red to port, as also a semaphore arm of the same color. The normal condition of these is, lights masked and arms down. If the helm is put to either side, on seeing a vessel approaching, the officer of the deck by working a lever either unmasks the corresponding light or raises the corresponding arm.

D. H. M.

# BOOK NOTICE.

AZIMUTH: A TREATISE ON THIS SUBJECT. By Lieutenant-Commander Joseph Edgar Craig, U. S. Navy. New York: John Wiley & Sons.

We are pleased to acknowledge the receipt of "Azimuth: A Treatise on this Subject," by Lieutenant-Commander J. E. Craig. The masterly manner in which the subject is treated shows that the author has given the subject many hours of careful and faithful study, and the results arrived at show that the old time and generally accepted theories, as to the best positions of heavenly bodies for azimuth observations, have been derived more from snap judgments than from penetrating mathematical deductions. As the author remarks, ordinary observations at sea do not exact the best conditions of observation, but there are doubtless many cases in which too much labor cannot be given to obtain the best results, and the author has pointed out the way in which this accuracy may be reached.

The treatment of the various loci discussed and drawn shows a deep and thorough knowledge of the subjects involved, and commends itself to the mathematical mind as a lucid and graphic illustration of how such a subject as this may be opened to the observer who will devote a few hours to perusal and study.

We congratulate the author sincerely, not only on the subject-matter of his work, but on the attractive form in which he has presented it to the public.

# BIBLIOGRAPHIC NOTES.

ANNALEN DER HYDROGRAPHIE UND MARITIMEN METEOROLOGIE.

15TH ANNUAL SERIES, 1887, NO. 3. Studies of the ice in the harbor of Kiel. Hydrographic notes on voyage between Koepang, Island of Timor, to Cooktown. The Island Ascension. Notes on Benguela, Santa Maria Bay, and Mossamedes, on the west coast of Africa. The Island of Mackau, Corean Archipelago. Notes from the voyages of several German merchant captains. Report on the harbor of Zebu, Philippine Islands. Pauta Delgada, Island of St. Michael, Azores. Instruments for measuring currents, and current measurement in the Bosphorus. Deep-sea sounding in the North Atlantic. Current observations, temperature observations, North Atlantic. Tracks of typhoons around Japan, and hints for avoiding them. Rains in the Indian Ocean. Short notices. Tables of average temperature, meteorological and magnetic observations.

E. H. C. L.

SERIES 1887, NO. 4. Observations on the Earth's Magnetism by the Polar Expedition, 1882-3. The Malimba and Blundo Rivers, south coast of Africa. Expedition of the Fylla to Baffins Bay in 1886. Meteorological and Hydrographic Notes: Part V. Samana Bay, San Domingo, West Indies. Nimrod Sound, China. Geographical, Meteorological, and Hydrographic Notes. J. T. S.

BULLETIN OF THE AMERICAN IRON AND STEEL ASSOCIATION (quoting from the *Iron Trade Review*).

The use of petroleum as fuel.

This fuel is used successfully in the Bay State Steel Works, South Boston, Mass., but has been abandoned on the steamers of the Union Pacific Railroad. Dr. Kauffmann reports to the Russian Government that petroleum can be solidified into bricks and still retain its calorific properties. He says: "Petroleum, which is a hydrocarbon of the methane group, may be saponified just like the oils, fats, fatty acids, and wax, thus oxidizing the oil and combining it with soda or potassa salts. For this purpose the oil is heated and from one to three per cent of common soap is added, with which it is boiled for half an hour. The soap dissolves and the fluid turns suddenly to a hard, putty-like substance. It lights with difficulty, burns slowly without smoke, producing great heat, and leaving about two per cent of odorless, black, hard residuum."

W. F. W.

BULLETIN OF THE AMERICAN GEOGRAPHICAL SOCIETY.

No. 3, 1886. Florida and the West Indies. Over the Mexican plateau in a diligence. Geographical Notes.

No. 4, 1886. Some of the geographical features of South-eastern Alaska. The origin of the name America. On the extermination of the great Northern sea-cow (*Rytina*). Ancient habitations of the Southwest. Geographical Notes.

No. 5, 1886. Table of contents, etc., for Vol. XVIII. Transactions of the Society for the year 1886.

No. 1, 1887. Oceanic Islands: their physical and biological relations. New Mexico: its geography, scenes, and peoples. Stone-Pasha's work in geography. Geographical Notes.

No. 2, 1887. The great walled river. Recent explorations in Egypt. Colonel Chaillé-Long on the Juba. Geographical Notes. Obituary: Vice-President Roswell S. Hitchcock, D.D.

J. H. G.

ENGINEER.

April 15, 1887. Compound versus triple expansion marine engines.

The same engine was worked alternately as compound and triple expansion, and the conclusion deduced that more I. H. P. per pound of coal was obtained in the latter case, but more knots per ton of coal in the former.

The Italian ship Dogali had her official trial trip, and is the fastest cruiser afloat. The mean speed over the measured mile was 19.66 knots; I. H. P. 7600; revolutions, 154.

W. F. W.

ENGINEERING.

February 25, 1887. Torpedoes and war ships.

April 1. Torpedo boat trials (from Proceedings of Institute of Naval Architects).

Results of trials to determine the value of $m$ in the formula $v = m\sqrt[3]{\frac{\text{I. H. P.}}{B^2}}$ (the usual formula employed in France). $B =$ area of midship section and $m$ a coefficient of efficiency. The value of $m$ was found to increase up to 11 knots, attain a minimum at 17 knots, and to increase slightly at higher speeds.

Paper on the twin-screw torpedo boats Wiborg and El Destruidor (from Proceedings of Institute of Naval Architects).

Valuable paper on scientific iron founding, with special reference to mechanical character and chemical composition.

April 8. On the corrosion of iron and steel ships.

With the aid of a galvanometer it was found that rust is quite as capable of setting up galvanic action as the magnetic oxide, even if the action be less intense.

Liquid fuel experiments.

A trial of a new furnace invented by Lieutenant Pashinin and used on a river steamer in Russia, showed that 1 pound of petroleum refuse evaporated 15.6 pounds of water, or 2¼ times as much as 1 pound of coal.

Paper on fuel supply in ships of war.

APRIL 15. Comparative effects of belted and internal protection upon other elements of design of a cruiser (from Proceedings of Institute of Naval Architects).

Last week the trials of H. M. S. Anson were made with 94 pounds of steam and 97 revolutions; the I. H. P. was 8320 and speed 16½ knots; consumption of coal 2.3 pounds per I. H. P. With both screws working ahead the port half circle was turned in 2 minutes 28 seconds; the complete circle, 640 yards diameter, was turned in 5 minutes 15 seconds. The starboard half circle was turned in 2 minutes 46 seconds, and the complete circle, 650 yards diameter, in 5 minutes 47 seconds. On the forced draught trials the steam pressure was 101 pounds; revolutions 108.6 port, 108.9 starboard; I. H. P., 12,568; consumption of coal 2.2 pounds per I. H. P.; speed, 17.4 knots..

On high-speed twin screws (from Proceedings of Institute of Naval Architects), with following table:

*Particulars of Some Recent High-Speed Twin Screws.*

| SHIP. | A. | B. | C. | D. | E. |
|---|---|---|---|---|---|
| Length in feet | 325 | 315 | 300 | 220 | 250 |
| Breadth | 68 | 61 | 46 | 34 | 32½ |
| Draught on trial { Forward | 26′ 2″ | 24′ 6″ | 15′ 6″ | 12′ 10″ | 13′ 1″ |
| Draught on trial { Aft | 27′ 3″ | 25′ 6″ | 19′ 9″ | 15′ 2″ | 14′ 7″ |
| Displacement in tons | 9690 | 7645 | 3584 | 1560 | 1544 |
| I. M. S., square feet | 1560 | 1287 | 744 | 438 | 392 |
| Speed of ship, knots | 16.92 | 17.21 | 18.18 | 16.91 | 17 |
| I. H. P. | 11,610 | 10,180 | 6160 | 3115 | 3045 |
| Revolutions per minute | 107.2 | 88 | 122.6 | 150.4 | 132.1 |
| Pitch of screw | 19′ 5″ | 22′ | 17′ 6″ | 12′ 7½″ | 14′ 9″ |
| Slip, per cent | 17.6 | 10 | 14.2 | 9.7 | 11′ 4″ |
| Diameter of screw | 15′ 6″ | 18′ | 13′ | 10′ 6″ | 11′ |
| Diameter of boss | 4′ 4″ | 4′ 11″ | 3′ 5″ | 2′ 9″ | 2′ 10″ |
| Number of blades | 4 | 4 | 3 | 3 | 3 |
| Blade area of one screw | 72 | 87 | 47 | 24 | 24 |
| $\frac{\text{Pitch}}{\text{Diameter}}$ | 1.25 | 1.22 | 1.34 | 1.2 | 1.34 |
| $\frac{\text{Disc}}{\text{Blade area}}$ | 2.62 | 2.92 | 2.82 | 3.6 | 3.96 |
| Immersion of screw | 9′ | 5′ 3″ | 4′ 4″ | 2′ 9″ | 1′ 10″ |

APRIL 29. Twin-screw torpedo boat (illustrated).

This boat is one of two built for the Italian Government by Yarrow & Co. Its length is 140 feet; beam, 14 feet; displacement, 100 tons; mean of six runs on measured mile in rough weather, 25.1 knots; revolutions, 274½; steam, 130.

The belted cruiser Orlando.

Her length is 300 feet; beam, 56; displacement, 5000 tons; draught forward, 20 feet, aft, 22 feet. The trial was for four hours with forced draught of $1\frac{1}{4}$ inches and the vessel loaded down to water line. Steam pressure, 129 pounds. Total I. H. P. 8622. The helm was put hard over (70°) in thirty seconds, and the circle, 480 yards, was made in three minutes, the shortest time in which it has ever been done by a vessel of her length. On the measured mile a mean speed of over $19\frac{1}{4}$ knots was attained, the highest ever attained by a British armed vessel.

A fast torpedo boat.

This boat, built by Thorneycroft & Co. for the Spanish Navy, attained a mean speed of 26.1 knots on a recent trial. Her length is 147 feet 6 inches; beam, 14 feet 6 inches; draught, 4 feet 9 inches.

Triple-expansion engines.

A comparison of the results of the working of eleven compound and nine triple-expansion engines showed a gain in economy of about 25 per cent in favor of the latter. W. F. W.

JOURNAL DU MATELOT.

APRIL 24. Interesting account of the use of oil in a violent storm, by the steamer Dragut.

MAY 29. Means for preventing collisions, a system of sound signals, by Captain Frémont, of Havre, France. D. H. M.

MECHANICAL ENGINEER.

FEBRUARY 26. Account of the testing and breaking of one of the steel shafts made for the U. S. S. Boston.

MARCH 26. Article on modern high-speed marine engines, giving a number of details.

MAY 7. Cost of electric lighting of vessels (from report of P.-A. Engr. G. W. Baird, U. S. N.).

The expenditures for one year were as follows:

| | |
|---|---|
| $14\frac{3}{4}$ tons of coal, at $5.17 per ton | $76 25 |
| $43\frac{1}{2}$ gallons of oil, at 55 cents per gallon | 23 92 |
| 149 lamps, at 35 cents | 126 25 |
| 34 3-light safety plugs, 18 of 6 lights, 1 of 30 lights | 4 24 |
| 2 key sockets, 4 plain sockets | 3 80 |
| 3 wire shade holders, at 30 cents | 90 |
| 3 pounds copper wire, at 40 cents | 1 20 |
| 2 pounds insulation tape, at 50 cents | 1 00 |
| $1\frac{1}{2}$ gross assorted screws, at $1.25 | 1 87 |
| 46 feet flexible cord, at 15 cents | 6 90 |
| 4 attachment plugs, at 40 cents | 1 60 |
| 3 dynamo brushes, at 60 cents | 1 80 |
| 1 standard, at 44 cents | 44 |
| Total | $249 98 |

The dynamo was in operation 1574 hours 26 minutes, and during that time a mean of 47 lamps were in circuit. The cost of the light was .042 cent per candle power per hour. The mean life of a lamp in the engine room was 932 hours 54 minutes. These lamps were in circuit all the time, and were lighted and extinguished by the starting and stopping of the dynamo.

### The forced draught system on the U. S. S. Alliance.

The system was devised by the Bureau of Steam Engineering, and by it the I. H. P. per square foot of grate was increased from 4.02 to 12.38. The ash pan doors are closed instead of the stoke hole.

### Test of steel screw blades for the U. S. naval cruisers (made by P.-A. Engr. C. R. Roelker, U. S. N.).

The strain put upon the blades was in each case 2.3 times the maximum which would occur with the blade in use. The deflection was remarkably uniform, and increased gradually from root to tip. W. F. W.

## RAILROAD AND ENGINEERING JOURNAL.

### May. Ribbed boiler tubes.

These tubes have longitudinal internal ribs, invented by M. Chomienne, and are manufactured in France by "La Societé Industrielle et Commerciale des Metaux." It is said they can be made almost as cheaply as smooth tubes, and are just as easy to sweep with the tube brush. Comparative trials of smooth tubes and ribbed ones in the boilers of a steamer on the Rhone, showed in one case a saving of 35 per cent, and in another case a saving of 24 per cent by the use of the latter tubes. By changing from smooth to ribbed tubes in one case, the heating surface was doubled and the calorimeter reduced only one-fifteenth.

### June. Large steel castings.

The Standard Steel Casting Co., of Thurlow, Pa., recently turned out and shipped to Philadelphia, a steel stem casting weighing 15,000 pounds for a gunboat building by Cramp & Sons, and a stern casting weighing 13,000 pounds, the first of cast steel ever made in the United States. Also sixteen cast-steel propeller blades for the Chicago, Boston, and Atlanta. The weight of each blade for the former ship was 2410 pounds, and for the two latter ships 3750 pounds. W. F. W.

## REPORT ON EXPERIMENTAL FIRING AT THE CAST STEEL FOUNDRY OF FRIEDRICH KRUPP, AT THE PROVING GROUNDS AT ESSEN AND MEPPEN.

### No. 67, 1887. Tests of experimental firing with 8.4-cm. rapid-firing ship's guns L/27.

The gun itself remains as previously described, excepting a change in the chamber to suit the new combined cartridge and shot. The carriage has been considerably modified, the lower pyramidal carriage resting on balls, on which it trains. The recoil of the upper carriage is taken up by hydraulic cylinders. The gun is elevated by an endless screw working into a toothed arc. The training is effected by a similar arrangement. Weight of projectile 7 kg.; charge, 1.6 to 1.7 kg.; cubical powder (?) of 10 mm.; initial velocity, 470–480 m. With a trial powder the initial velocity vas increased to 506 m. It takes three men to work the gun; one man sits on the seat and sights the gun. He has the firing string attached to a belt around his body. He fires by throwing his body

back. Rapidity of fire, 10 shots in 34 seconds, or at the rate of 18 shots a minute. They were fired at the bow of a torpedo boat, distant 400 metres. The middle fore and aft line of the bow was in the line of fire, and the bow plates stood at 15° to each other and perpendicular on the ground. The steel plates had strength of 5 m. All the shot hit, as will be seen on diagram. Later 7 shots were fired in 19 seconds, or at the rate of 22 per minute. Therefore, in one minute $7 \times 22 = 154$ kg. weight of shot can be fired with $80{,}000 \times 22 = 1{,}760{,}000$ m. kg., *vis-viva*. This is the best result yet obtained by rapid-firing guns.
E. H. C. L.

REVUE DU CERCLE MILITAIRE.

No. 12, March 20, 1887. Military forces of Canada.

No. 13, March 27. Torpedoes and torpedo boats. The French fleet, January 1, 1887. New infantry equipment in Germany.

No. 16, April 17. New equipment for French infantry.

No. 17, April 24. Trials with the Maxim revolving guns. Experiments with new repeating rifle at Vienna, Austria.

No. 19, May 8. Launch of Austrian turret vessel, Princess Stefanie, at Trieste, giving general description, armament, lighting, and machinery.

No. 23, June 3. New equipments for German infantry, giving several different views.
D. H. M.

REVUE MARITIME ET COLONIALE.

May. Instrument for self-registering the rolling of a ship. The Legion of Honor (continued). Study on the combined operations of fleets and armies, commencement of Volume V., Volumes I., II., III. and IV. having been published in 1882–'83. Austrian expedition to the Island Jan-Mayen (continued). Observations made at New Foundland on board the frigate La Clorinde during the cruise of 1886.

June. Continuation of the combined operations by sea and land. Under the head of "Chronique," or selections from other papers, is an article from the Marine Engineers, describing an apparatus intended to signal the position of the helm to an approaching vessel. The position can be shown either at day or at night. (See Professional Notes, present number.)
D. H. M.

RIVISTA MARITTIMA.

February.

"...ench Minister of Marine has issued a circular, from which the follow-
...tracted with regard to the care of the boilers of torpedo boats.
...ting fires the blowers are not to be used, but natural draught is to
...d upon. The fires are not to be urged, but to be regulated in such
... a steam pressure will begin to show after one and three-quarter

hours. Allowing ten or fifteen minutes for the pressure to rise to five or six kilos, it will be two hours from the time of lighting fires before the torpedo boat is ready to move. The blowers will not be started until the torpedo boat is in motion, and then only gradually. When the torpedo boat is in motion, except in case of absolute necessity, of which the commanding officer is to be the sole judge, all sudden changes of speed are to be avoided, and especially all sudden stops when the engine is working full power. Changes of speed both of the engine and of the blowers should be made gradually and progressively. The doors of the boiler compartments should never be entirely opened or shut at once, but gradually. When the fires are to be hauled, the steam pressure should be allowed to fall some time before the engine is stopped, and at the same time slow down the blowers gradually, aiming to stop them just as the engine stops. The steam pressure may be relieved either through the safety valves or the bleeding valve to the condenser. If, when the engine is stopped, the fires are heavy, they may be partly hauled by taking out a few of the grate bars. If, on the other hand, they are not too heavy, they may be left as they are. The furnace and ash-pit are then to be shut air-tight, the cover put on the smoke-pipe and on the air-pipe from the blowers, and then, or at least on the following day, the boiler compartment is to be shut and left to cool down gradually.

The Minister of Marine has proposed a reorganization of the corps of the Navy, the most important change being in the Engineer Corps (Ufficiali Meccanici), who were to be completely assimilated (in rank—W. F. W.) to the line officers, the highest to have the rank of fleet captain (Capitano di Vascello). The parliamentary committee, to whom the proposed law was referred, did not favor the changes, and especially that relating to the status of the engineers. W. F. W.

## TRANSACTIONS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

### Vol. VIII. The new calorimeter.

Paper giving tabulated results of boiler tests made with a new calorimeter. This instrument works on an entirely different plan from any other. The principle of operation is to evaporate the moisture held by the steam, and measure its quantity by determining the amount of heat required for this purpose. The instrument is described at length in Vol. VII., p. 178, of the Transactions.

### Capital's need for high-priced labor.

The paper and following discussion treat of the wage question at length and in detail. The conclusion is reached that, "as a general rule, large wages return many times as much value to the shops as low wages." Also it is better to pay each laborer in proportion to what he does than to pay the same wages to all engaged in the same class of work. W. F. W.

## UNITED SERVICE GAZETTE.

March 26. Convoys; are they any longer possible?—discussion on.

April 2. Belligerent rights; and what is lawful in war time—discussion on. A new gun for the Royal Navy, Armstrong, is a 30-pounder, weight with carriage 92 cwt.—intended for repelling torpedo attacks. Carriage fitted with Vavasseur's patent automatic machinery. Muzzle velocity 1900 feet.

APRIL 16. Improvements in camp kitchens, field cooking, camp equipage, and military transport. Trial of a new plate made by Cammell & Co.; no shells penetrating, the steel shells being completely broken up.

MAY 14. Launch of the Sans Pareil at Blackwall.

Dimensions: Length, 340 feet; breadth, 70 feet; depth, 37 feet 6 inches; displacement, 10,470 tons; engines, 7500 to 12,000 H. P. Armament, two 16-inch 111-ton guns, twelve 6-inch [illegible], nine 3-pounder quick-fire, one 10-inch 29-ton gun, twelve 6-pounder quick-fire, two 1-inch Nordenfeldt, eight 14-inch Whitehead torpedo tubes, and four 0.45-inch Nordenfeldt. The Sans Pareil has eighteen inches steel-faced armor.

Launch of the new composite sloop Buzzard.

Length, 195 feet; breadth, 30 feet; draught, 12 feet 2 inches; displacement, 1075 tons; 2000 H. P. Armament, eight 5-inch B. L. guns. Unarmored, but vital parts are protected by a steel deck running the whole length of ship.

MAY 21. An article on torpedo boats.

JUNE 11. Launch of the Immortalité at Chatham.

A twin-screw belted cruiser 300 feet long, 56 feet wide; draught forward, 19 feet 6 inches; aft, 22 feet 6 inches; displacement, 5000 tons; I. H. P., 8500; speed, 18 knots. Principal battery, two 9.2-inch B. L. and ten 6-inch B. L. Steel-faced belt ten inches thick, and iron plating at end of belting sixteen inches thick.

JUNE 18. Blockades under existing conditions of warfare. The second torpedo attack upon the Resistance. D. H. M.

LE YACHT.

MARCH 12. P. 84: Submarine boats. P. 90: Turnabouts, description and plans of these little vessels, French and English. P. 91: The new cruisers building in France.

MARCH 19. P. 95: The French manœuvres of 1887; a criticism on the orders given for the contests between the fleets and torpedo boats. P. 98: Hill and Clark's boat detaching apparatus, drawings and description. P. 101: El Destructor, giving dimensions, etc.; also, some of the chief faults in her construction.

APRIL 2. P. 115: The Nice, French cruiser for cadets. P. 116: Trial of the Camperdown's engines. View and description of the rudder of the Spanish torpedo boat (cruiser) El Destructor.

APRIL 9. P. 119: Torpedo boats and Mère Gigogne.

The Mère Gigogne is thus described: She will be designed to carry six torpedo boats, and will be an armored vessel, with 35-cm. plates, armed with two 34-cm. also repeating cannon and rapid fire guns. She must have great speed. [illegible] such a vessel have been advertised for, and she will probably cost twelve million francs.

P. 122: English sea-going torpedo boats.

This article mentions the Rattlesnake, Grasshopper, Spider, and Sandfly, giving dimensions, armament, and trials of speed of Rattlesnake.

April 16. P. 131: Description of Mr. Trouve's electric engines for small boats, showing plans of battery; arrangement for electric ventilator and fog horn and electric boat lights.

April 30. P. 145: Plan and description of apparatus for pouring oil on the sea from ships. P. 147: Manœuvres of torpedo boats in Mediterranean. System of protection against torpedo boats.

May 7. P. 155: Description and view of torpedo boat Ouragan. P. 156: Manœuvres of torpedo boats. Launch and description of the Neptune. Trial of cruising battery Sfax at Brest.

May 14. Before the manœuvres; referring to the operations about to be carried on by the French between a fleet of ironclads and a fleet of torpedo boats. P. 163: Trials of a new style of gunboat.

May 21. P. 171: Protection of fighting ships and Melinite projectiles. P. 173: Accidents at sea, and means for preventing them.

May 28. P. 181: Fog signals. P. 185: Launch and description of French iron-clad Marceau. The iron-clad barbette vessels of the English Navy. P. 186: The English torpedo flotilla.

June 4. P. 199: Recent auto-mobile torpedoes.

June 11. P. 211: Description and chart of the canal from the North Sea to the Baltic.

This canal was inaugurated June 3, 1887, by the Emperor of Germany.

End of article on recent auto-mobile torpedoes. D. H. M.

REVIEWERS AND TRANSLATORS:

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# PROCEEDINGS

OF THE

UNITED STATES

# NAVAL INSTITUTE.

VOLUME XIII.

EDITED BY
GEO. W. TYLER, CHAS. R. MILES,
W. F. WORTHINGTON.

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ammunition on another. He says: "We thus ensure all the companies in the regiment taking an interest in their own gun and training men for work with it." By giving a company as the allowance per gun there would be a sufficient number for a heavy drag, and the men not stationed on the drag rope would be valuable as an infantry reserve in action, or as guards on the march.

Referring to (p. 304) the attempt to organize the ship's company with the battalion as a basis, and again, on p. 310, as to regulations of Ordnance Manual, I would suggest that companies should first be formed and then apportioned to a ship as may be necessary to fill the ship's fighting quota; there may be a few extra men, but better so than too few. To support my position I will quote some words of General Von Kraft, to whom the essayist refers on p. 329. "My desire is that elementary tactical instruction should be completed in the company instead of being carried on, as now, in the battalion. Hence the company has become the real tactical unit." And again, from General Sir Lumley Graham's work: "The importance of the company as a battle unit is much increased, and *pari passu* the importance of the captain as a commander."

Neither the powder nor the engineer's divisions should be landed. They are now the two most necessary divisions on board ship, and in the event of a landing in an enemy's country, they are the ones who should be left to protect the ship. For this purpose the engineer's division should be thoroughly drilled in the management of all guns, and then, in case of attack during the absence of the brigade, the men on watch could manage the engines, while the men off watch handled the guns with the assistance of the powder division. The handling of charges and projectiles will be the turning point in an engagement, and for that reason the powder division should not be interfered with in the slightest degree, lest its efficiency should be impaired.

On p. 311—I wish the essayist had specified a little more clearly from what ships the twenty companies and the ten pieces of artillery are to be drawn. It is easy to say, land so many men, but the thing is to detail them to the different ships according to their rates. With such a detail made out an admiral or commander of a fleet could tell at a glance just how many men he could land; that is, how many companies and pieces of artillery. There should be a fixed and unalterable plan. At the present time too much is left to the executive officer, and that accounts for the "very dissimilar battalion organizations." Should such a plan be adopted, an executive officer would be spared much trouble, and would have more time to devote to his present onerous duties.

From the same page it would appear that two medical officers are enough for the brigade. I think that there should be one surgeon to every battalion of three companies, besides the surgeon on the staff—remembering that there must be some detached work. The allowance of two surgeons to 1295 men (not counting the officers) is clearly insufficient.

As to the pioneers (p. 311), it must be allowed that they will have plenty to do without helping the ammunition passers. The pioneers should correspond to the army engineers, and should be drilled in such work as generally falls to the lot of the army engineer.

On p. 312 it is suggested that the marines should be landed in boats pulled by sailors. The objection to this would be the number of sailors required to pull a certain number of marines ashore; if the marines cannot pull themselves (as they should), send them ashore in steam launches. As to the Intelligence Staff (p. 312), I think it would be desirable to have the officers from the Office of Intelligence on the immediate staff of the commander of the brigade. It is to be supposed that, being sent from that office, they will be well acquainted with the country in which they are to serve, and on that account should be continually near the commanding officer. On p. 313 is mentioned one signal officer; he should be in charge of all signal men, and besides being headquarters signal officer he should be an aide to the brigade commander.

In regard to the equipment of the sailor (p. 315)—for a firearm the Lee magazine gun is to be preferred. With it the sailor is not given the opportunity to use the magazine nearly as much as with a rifle which carries its magazine in the stock. The magazines for the Lee are easily carried in the waist belt, and by one simple movement a man, if hard pressed, is given command of five shots. With a stock-magazine rifle he will, in nine cases out of ten, have emptied the magazine in his hurried advance to the fire line, and at the moment of his greatest danger he will have an empty magazine and have to resort to loading by hand. Only by continued fire-practice can the critical moment be so guarded against that the men may always be provided with ammunition. This must be brought about, as Prince Hohenlohe says, "by repeating the simple routine"—the context shows that he means a real action exercise—"hundreds and thousands of times."

I must differ from the essayist as to the arming of a gun's crew; they should *all* be armed with magazine rifles, preferably with the Lee. It will be necessary, at some stage of an action, to change the men serving the guns. Will they have time to change their belts and equipments so as to keep the men stationed at the guns uniformly armed? If they will not have time, why make any difference in the equipment of the crews?

On p. 315 the proviso is made, "should limbers be landed." There should be no limiting word, the instructions should read—limbers will always be landed with pieces; in fact, it should be made as hard for our landing party to drag the piece alone as it is for the army. What would a field-piece be worth without a limber?

The same objection obtains in regard to arming the limber's crew (p. 316) as in regard to the gun's crew. As to shields for artillery, if these shields can be made a part of a gun carriage, serving to support the ammunition boxes when on the march, have them by all means; but if they are to add extra weight to the already heavy gun, do not have them.

Again (p. 316) I must differ from the essayist in regard to cutting down the supply of ammunition for light marching order. Powder (or ammunition) is what you must depend upon when you reach the point towards which the march is directed. Light marching order is such as will admit of quick, forced ·hing. It will be necessary at a time of great danger and when it is sup- the fighting will be short, sharp, and decisive—at a time when the force

will be able to return very soon, and consequently at a time when you should carry plenty of ammunition and doff the knapsack and other unnecessary weights.

It is well said on the same page that the sword is useless; it is worse than useless, it is in the way. So also with the bayonet; it will be of no use to a naval brigade if opposed to a body of troops armed with magazine rifles—if such weight is to be carried it should be as an entrenching tool.

The idea of a man carrying a blanket encircling the body, over the left shoulder (p. 317), should be done away with. In the recent orders issued to the armies of France and Germany this way of carrying the blanket is relegated to obscurity. In hot weather a blanket carried in this way is almost insupportable—in any weather it is in the way. The knapsack and blanket should be carried on the back, not to project more than two inches above the line of the shoulder.

In his reference to tents, on the same page, I presume the writer merely refers to landing for drills. It seems rather strange to think of men landing in an enemy's country with capstan bars and boat spars with which to erect tents. Let us rather rig our hatches with a different style of canopy frame, and have all covers made in the form of a tent, provide plenty of extra covers, with pipe poles and wire or pipe ridge poles, and there will be plenty of tents, taking up but very little room, and rendering unnecessary any application to the army for tents, or the carrying ashore of spars and sails.

On the same page medical officers are allowed to wear swords. Why? So that they may trip over them when hurrying to assist some wounded man? And why take ashore a master-at-arms and a ship's corporal? They are efficient petty officers on board ship, but spare Jack the sight of them ashore. It is provided (p. 318) that each officer and man shall have a piece of painted canvas to sleep upon, and it is suggested that a tarpaulin makes an admirable bed; there is, however, no consideration of the weight of these things. Can any one picture to himself the struggle *two* men have with *one* tarpaulin when covering a hatch at fire quarters!

In regard to the mounting of some of the officers—be sure they know how to ride before you put them on horseback. It is not a pretty sight to see an officer riding up Broadway holding on to the pommel of the saddle to keep himself down in his seat. When the brigade is under fire is just the time for all officers entitled to be mounted to be in the saddle, so that the colonels may give attention to such parts of their command as need encouragement, and that the aides may be ready to carry messages to the different parts of the field.

Passing over the tables of light and heavy marching order, we find given on p. 321 the strength of the Naval Brigade. Not knowing into how many battalions the twenty companies are divided, I can say nothing as to numbers, officers, etc., so I will only refer again to the paucity of surgeons and signal men, and, as regards the artillery, to the insufficient number of men for the work required.

The pioneers are very much handicapped (p. 322) by having to carry 13 pounds (tools, and a bag of miscellaneous implements); besides, 30 pioneers for such an expedition are insufficient.

[illegible]

[illegible]

[illegible] water has been [illegible]

[illegible] remark that the [illegible] I think also that [illegible] a lottery [illegible] be performed at a [illegible] are done away with [illegible] tool shovel and [illegible]

pick combined), such as is now in use in the German army. By the increase of the gun's crew the infantry support can be assured. Before leaving this subject I wish to say that I gather from this essay that the artillery is to be drilled only as artillery and the infantry only as infantry. If that is the idea I wish to disagree, as I think a company of infantry should constitute the crew of a piece, and be as well versed in the management of the piece as in the manipulation of its own rifle.

The embarkation of the brigade in boats well merits all that the essayist has said—he might have gone further and said that our present boats are not fit for a first class navy. Why have larger and smaller boats? Why, with the new ships, can we not have a new style of steam launch, pulling cutter, and light pulling life boat? Why cannot these boats be all alike in their classes, and have these classes of the best? To what does the essayist refer when he speaks of heavy boats? Does he propose to keep the pulling launches in the service, to wear out a man's life before he has pulled one half mile? He can scarcely refer to any of our present cutters, for there are but few which will stand the continual fire of a 3-pounder B. L. rifle.

There is one point on which I do not think stress enough has been laid—that of getting the machine guns ashore dry and clean, and also trying to get the men ashore dry-shod. There is nothing that makes the feet sore more quickly than a pair of wet shoes filled with sand. Cannot our whale boats be so rigged as to be used as pontoons? I think so. With but little additional cost per boat they can be arranged for use as pontoons, and with two whale boats a bridge 30 feet long and 10 feet wide can be erected. Such an arrangement as this would be of much service if landing where the sea is not too rough, as also in crossing small rivers and streams. These whale boats should be manned by the pioneers (artisans), who should also, in boat evolutions, be used to repair damages to the fighting boats.

In speaking of stoves (p. 331) the essayist mentions no particular stove, so I suppose he refers to the old boat stove. A more useless article of furniture it is difficult to imagine. One has been invented in Germany which cooks well, is light, and by a few changes could supply all that is required of a campaign stove.

As for disembarkation it is to be said that "circumstances alter cases," that at present we have but about four vessels to a fleet, and that the electric search light is comparatively new to us and not generally supplied to our ships, so that the remarks on this point help us but little at the present day. As to marches, the words, "the commander of the expedition will decide how the march is to be taken up," say almost all that is necessary.

In the remarks on quelling a riot the words—"*if forced* to fire on the mob, use ball cartridge, and never fire over their heads"—might be introduced. A few lives sacrificed at the beginning will save much trouble and much bloodshed.

In conclusion I must say that I can see in the essay no definite plan of organization. For the success of the Naval Brigade it is necessary that it should be under a permanent head; that it should be governed by rigid r

for the carrying out of which commanding officers should be held responsible. Until this is done we are bound to have a different way of doing in each of our squadrons, varying according as the ideas of the commanders of those squadrons vary. Uniformity in drill, strict attention to the [illegible] and skirmish exercises, and continual practice are necessary before we can expect to realize anything like a perfect Naval Brigade.

Lieutenant COLAHAN.—*Mr. Chairman and Gentlemen*:—In regard to increasing the number of men allowed in a company, I consider the present number—thirty-six—as the one most conveniently supplied from the gun divisions of ships of any size. I consider this number also as a maximum for the artillery sections with limbers. I do not think it advisable to arm all the artillery force with the rifle—one half would be quite sufficient. Men in heavy marching order would have quite enough to carry without the rifle; there should be at least half the section as unencumbered as possible, so as to be able to do good service at the drag rope. These could be armed with revolver alone, while the other half would be armed with the rifle as infantry support. The latter could assist, if necessary, at drag rope and relieve the regular numbers stationed at the ropes.

I believe that some form of bayonet is necessary, and suggest a knife bayonet somewhat after the style of the Spanish machete, though not so large, say about ten inches long. This would be serviceable as a bayonet as well as for clearing any underbrush on landing or on the march, and would be of general usefulness as a knife.

The necessity for some means of transporting extra ammunition for Gatlings and small arms, as well as stores and cooking utensils, was made manifest in exercises of N. A. Squadron. A cart, two wheeled, of the same gauge as the artillery carriage, provided with tongue and side drag ropes, should be issued to all ships. Independently of its use with the brigade, it would soon pay for itself in ordinary ship's work.

The idea of using capstan bars and sails for tents is a poor one, even for a camp of instruction. They are excessively unwieldy and heavy. At the camp at Gardner's Island they had to be hauled up the bluff with tackles, causing great fatigue and trouble, as the beach master, Lieutenant Belknap, can testify. They would be utterly useless on an expedition on shore. The shelter tent and rubber blanket would be all the protection necessary for the limited stay on shore required of the Naval Brigade.

Lieutenant-Commander HUTCHINS.—*Mr. Chairman and Gentlemen*:—The difference of opinion expressed by Lieutenant Mahan on the essay calls for a few remarks in reply.

In the first place, it is not necessary to change "the orders in the tactical books," but to confine ourselves to *tactical language*. I very much doubt if any fighting will be done hereafter without ammunition passers and carriers. At present we have no facilities for making up an ammunition train on shipboard, and somebody must carry ammunition. An examination of the essay

will show that I have sifted the words of General Von Kraft, as well as those of Captain Walter H. James, referred to by Lieutenant Mahan. The essay states, "Extra belts can be filled with cartridges and packed away in canvas bags, to be served out in an emergency." I hold that the belts filled serve the purposes of the Naval Brigade better than filling men's pockets with ammunition.

Lieutenant Mahan states, "The artillery company is *much* too small; sixteen men to the piece and seven additional for the limber would make but sorry work on the march. In the Egyptian campaign, a crew for a Gatling gun was composed of thirty men, and in addition thereto four mules." Commander Goodrich, who is authority on the Egyptian campaign, 1882, states that "the actual crews were each of 24 men,"—just one more than I have allowed in my organization. In the Egyptian campaign fourteen of the men in the gun's crew were armed with rifles, the rest of the detachment with cutlasses and revolvers. Twenty-three men to an artillery company appears to be about the number necessary. Were we to go on an expedition like the Egyptian campaign, referred to by Lieutenant Mahan, we would do exactly what the English did at that time—provide mules or horses to drag the artillery, and increase the number of men at each piece, to be used as *stretchermen, mule and baggage guards.*

When General Von Kraft referred to a company he did not mean forty-six men, neither did he mean sixty men; the German infantry company is more than double the size of the average ship's battalion of infantry; dividing the company into four sections, there is an officer to command each. Lieutenant Mahan states, "It is easy to say land so many men, but the thing is to detail them to their ships according to their rates. With such a detail made out, an admiral or commander of a fleet could tell at a glance just how many men he could land—that is, how many companies and pieces of artillery .... At the present time too much is left to the executive officer." The Bureau of Ordnance puts on board each vessel of the Navy a fixed number of small arms, according to her class, also so many pieces of artillery; consequently, to detail the men is one of the easiest as well as one of the simplest things an executive officer of a ship has to do; in fact, the Bureau of Ordnance settles this matter, and any admiral would know how many men each ship will land by a glance at the ordnance return of arms, guns, etc. The executive really has nothing to do with the number of men the ship is to land; he has but to use all the small arms (rifles) and the guns put on board for the artillery.

By reference to the essay we will find the following on blankets: "There is no reason why men should not be furnished with light canvas knapsacks for carrying blankets and clothing." One of the latest German naval expeditions, to Witu, August, 1885, the men carried no knapsacks. Notwithstanding "the recent orders issued to the armies of France and Germany, this way of carrying the blanket is relegated to obscurity," as stated by Lieutenant Mahan. I was not aware that the armies of any country carried their blankets in any other way except on the knapsack; in fact, I was under the impression that the relegating spoken of by Lieutenant Mahan occurred

[illegible] Mahan [illegible]aving
made [illegible] pieces," [illegible]
of [illegible] serve to support
[illegible] [l]imbers, ammunition

boxes go on them, and *not* on the gun carriages. Of course, if you are going to load down both the gun and limber with ammunition, it will be necessary to have larger gun's crews, and larger than the English had in the Egyptian campaign, for *they* carried their ammunition on the limbers.

In speaking of the electric light, Lieutenant Mahan states that "the electric light is comparatively new to us and not generally supplied to our ships, so that the remarks on this point help us but little at the present day." About one-fifth of our cruising force have been and are being fitted with the electric light. It is one of the most important adjuncts with which the Naval Brigade can be equipped. It is now being experimented with at the War College, and I can speak from experience in Egypt that it is invaluable to a landing party, when used from the masthead of a ship.

In concluding these remarks, I regret that my plan of organization is not definite enough to be seen from Lientenant Mahan's standpoint. I appreciate his friendly criticism, which has brought up some points that I had supposed were generally known throughout the service. Criticism, particularly of a professional subject, can carry no weight with it, however, unless sustained by something beyond the mere statement of a difference of opinion.

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## NEWPORT BRANCH,

OCTOBER 12, 1887.

Rear-Admiral S. B. LUCE, U. S. N., in the Chair.

Commander BAINBRIDGE-HOFF.—*Mr. Chairman and Gentlemen*:—My remarks can hardly be termed a discussion of Lieutenant-Commander Hutchins' essay, but I am led to make the following remarks as germane to the subject. Mr. Hutchins places his boats to land in line. This means varying speeds and different instants of landing. Some boats will be under fire longer than others. The quickest way to get your boats in and have the crews land together is to come in columns—three or four of them—towed in by the steam launches. These launches should carry Gatlings, and then we would have machine-gun boats leading in with quick fire. The tows should cast off and the boats land in groups on the beach, before the water became so shoal that the steam launches would be in danger of taking the bottom, which they should never be permitted to do. Steam launches should never be used to carry men, and should have a Gatling or rapid-fire gun which is not to be landed. They must be the gunboat flotilla to protect the landing.

In regard to manning boats for landing, I believe in the "platoon system"—the system of sixteen. Not only should the landing bill be founded on it, but ALL bills on board ship should be founded on this system. It is a nine-inch gun's crew; it is a boat's crew; it is half a company; it is a howitzer crew, and an engine-room watch. It can handle a sail, it can clean a part of the ship; and if we adopt the newer system for supplying rifled guns—i. e., suppressing

the powder division—it forms a chain from magazine beside the gun's crew. It should have always two leaders associated with it—a boatswain's mate and a quarter gunner. All rates, such as captain of top, coxswain, ship's corporal, should be abolished. A ship should be entitled to so many platoons. Each platoon should be composed of four landsmen, six ordinary seamen, and six seamen. There should be one officer allowed to each platoon.

Mr. Hutchins puts his artillery boats in certain positions. This I consider bad, as it makes a hard and fast rule. Artillery boats, confined to arms firing larger ammunition than shoulder rifles, should be placed where needed. Gatling guns should be considered an infantry arm.

Lieutenant A. C. DILLINGHAM.—*Mr. Chairman:*—In considering or discussing the very able essay by Lieutenant-Commander Hutchins, I begin by agreeing with him in this, that "there has been, and always will be, some opposition by naval men to the Naval Brigade, and to the landing of sailors for operations on shore."

That every squadron should have an organization capable of operating on shore in case of necessity has been demonstrated not only by the navies of foreign countries, but since I have been in the service, by our own navy; for instance, the operations of Admiral Bell at Formosa in 1867, of Admiral John Rodgers in 1871 at Corea, and again more recently by the operations conducted on the Isthmus of Panama. There may have been opposition on shipboard by the sailors to being landed as infantry, but the experiences we have had in the North Atlantic Squadron show us that to-day the men of the squadron consider it just as much their legitimate duty as the great gun drill or the crossing of top-gallant yards at colors.

Lieutenant-Commander Hutchins has observed with great care the most important element in connection with the organization and landing of a Naval Brigade; for it is only by the strictest attention to detail, as he says, that the success of the landing can be insured. The question of landing a Naval Brigade allows of so many circumstances that will govern the details, that I do not believe any positive rules can be laid down that will satisfy more than one case. All that we can do is to lay down the general principles, and by practice ashore under different circumstances be better prepared to meet an emergency. The details for an expedition should be most carefully considered, and once made should be strictly adhered to.

The squadron of the North Atlantic Station has greater facilities for carrying on the requirements of a Naval Brigade than any other squadron we have. It has our own shores to land upon, and has easy access to materials, so that it may be considered *the* squadron where such an organization should be perfected by practice. It would add much to the efficiency of our drills in this respect if we had some permanent place where all the equipment necessary for the Naval Brigade could be kept. Here the squadron could assemble and go into field for such drills or operations on shore as the commander-in-chief should think best.

I speak of this for the benefit of those whom I have heard criticise adversely

the brigade drills of the North Atlantic Squadron. They have said that "too much attention was given to the Naval Brigade—too much weight was given to its importance." These officers I believe to be in error, when we consider that the drill is a necessary departure from the customary drills of a man-of-war's man. If we consider the actual practice we have had in landing the brigade for drill, it has not amounted to more than is necessary to show those concerned that an organization of this kind is possible and efficient. There is something to be said, too, in favor of the parades or displays we have had; though tiresome to us in themselves, they have nevertheless brought the sailors before the public, and have allowed the public to realize that we still exist. We are obliged to patronize the public, and to allow the taxpayer to see that his money is expended for material.

The organization of the battalion on board ship should be, as far as possible, the key to the organization of the brigade. But the battalions of the different vessels of a squadron differ so much as to the number of men composing them, that a strict adherence to ship organization is not always possible.

The first point that I take issue with the essayist upon is this one: "In combining the battalions under one head, each ship's battalions should *land* and fall in together." Under these conditions the battalions of the different vessels *land*, and after landing the brigade is formed. This might be done if the landing is unopposed or not under fire; but if the force is to be landed under fire, such a plan I should consider almost fatal. Upon landing, the companies would have to go to the positions they would occupy in the battalions, and it might be that a company upon the right of the line would have to proceed to the left, on account of the rank of the commanding officer. Upon landing when opposed, it is necessary to obtain and maintain a position as soon as possible. Such a state of affairs as I have spoken of would be confusion, hence delay. Such a condition is by all means to be avoided. A brigade might be landed in this manner if unopposed, with plenty of time to organize ashore, but why have more than one system? If we always land as if opposed we are always prepared.

The organization of the brigade should take place in the line of boats, before going under fire, so that when the companies leave their boats they are in the proper positions in the battalion to which they belong. This is accomplished by each boat, after leaving its vessel, taking that position in line which would be occupied by the men it carries, in the brigade. A map of "order before landing" is made and distributed among the vessels. The position of each boat in line is here indicated, and the officers to be landed know exactly where to go. It is just as easy for boats of battalions to find their places, forming the brigade in boats, as to find their places as described by the essayist. This is the practice in the North Atlantic Squadron and it has worked to perfection. Upon landing there has been no confusion. The brigade was *formed*, and an immediate advance could be made.

I agree with the essayist, that the size of a company of infantry landed should be consistent with the number of men in a division aboard ship, and that men landed should be commanded by the same officers that they are under

[illegible]

[illegible] The North Atlantic Squadron, [illegible] companies, and [illegible]. I think that a battalion [illegible] consist of [illegible] companies. [illegible] maneuvered in three divisions. [illegible] a number of men [illegible] better [illegible] hand, and more [illegible]. I think it is not always desirable that the commanding officers of battalions should be the senior executive officers, as [illegible] in the essay. [illegible] the limited number of officers [illegible] plan of detail is good, but some officers have more aptitude than others for such service [illegible]. I believe a better detail would be one made by the commander-in-chief. The objection I see to this plan is that it excludes from brigade duty a [illegible] to the detail.

In considering the plan of "[illegible] before landing" I see no good reason why the skirmish lines should be in boats in advance of the main body. It gives more mass, consequently a better target, though it has the advantage of shortening the front. Supposing the whole front of a brigade should land on one beach, I suggest that the skirmish line be composed of the right company of the first battalion and the left company of the second battalion where there are only two battalions of infantry, as in the brigade of the North Atlantic Squadron. When the signal, "Skirmishers advance, land, and deploy," is made, the boats containing these companies pull to the shore, and upon landing, the right company deploys to the left, meeting the left company, which is deployed to the right. By this means the flanks are reached the sooner and the front covered

at once. The officer commanding the skirmish line will of course handle his line so as to cover the line of battle taken by the main body. The legitimate duty of the marines should be the first skirmish line; but, until they are capable of pulling and transporting themselves, this is impracticable. I see no reason why the marines should not be instructed in boat pulling and boat sailing. The best distribution at present for the marines is among the boats from their respective ships; they land with the main body, and after forming, proceed at once either to relieve or reinforce the first skirmish line. Putting them in the boats to be pulled by the men of the reserve, as suggested by the essayist, would cause confusion by separating this part of the reserve from the main body. If the first skirmish line is relieved, they assemble upon the battalions to which they belong and in their proper places.

The essay makes a rule for the position of the boats containing the artillery. There can be no hard and fixed rule for the position of the artillery, unless we consider the Gatling guns as a part of the artillery. These guns should invariably go with the infantry. As soon as the artillery is on shore the Gatling guns should be sent to the battalion commanders, who should place them to the best advantage with the infantry. Should the vessels of the squadron be able to clear and maintain a clear beach, then the artillery would form a second line and land after the main body, taking such positions in rear of the main body as the topographical features of the landing present. We would not attempt to drag artillery up a bluff, nor land it in the face of outlying rocks or shoals. Places should be selected where the guns can be landed with the least trouble, considering, of course, their future position after landing. It might be necessary for the artillery to be put in advance of the line, in event of the vessels being out of range and the contour of the shore being such as to prevent an enfilading fire. I mention these points in my endeavor to show that there can be no fixed rule for the position of the artillery before landing, it depending upon the circumstances of each particular case. The balsas now supplied make excellent rafts, and one should be towed astern of each artillery boat, to land the guns on if necessary.

I think that the proper use of the steam launches is not appreciated in landing the brigade. Generally they are loaded down with music and marines; they take the ground early, and in the endeavor to get them nearer to the shore [illegible] and use by being hopelessly aground. The steam [illegible]d means of communication between the shore and [illegible]e base of operations—the squadron. The steam [illegible]antage for towing, but they should be free to cast [illegible]der to be on hand to haul off the beach the heavier [illegible]en afloat by their boat-keepers. It is a most important [illegible] the boats have landed their men they should be [illegible]e, to re-embark them. We have had in this squadron [illegible] launches being put out of service by grounding. I [illegible]f each steam launch a revolving cannon or a rifle [illegible]rry only the men necessary to work these guns, [illegible]fter they have done the duty of towing, if thus

armed they would make an efficient patrol for the beach, and by their rapid moving power could be employed to cover necessary points within their range. At the operations on Coddington Point, had the steam launches been so armed, it would not have been necessary to weaken the artillery force by sending a platoon to cover the retreat of the brigade to Coaster's Island, as they could have taken, in that instance, such positions as to have performed this service thoroughly. A steam launch towing artillery boats, one on either side, would present an excellent and rapid-moving battery of three guns. The steam launch should carry the spare ammunition, which should be put ashore by some of the lighter boats before reaching shoal water. Of course, in operations at a distance from the squadron, ammunition and stores would go with the brigade; but in operating near the squadron, the steam launches could carry to the shore stores to be landed by the lighter boats, and these would be protected by the guns of the steam launch.

In landing the brigade, the boats are already loaded down with men and such articles as are absolutely necessary to be landed at once. I would say it is only the men and such articles as may be immediately needed that should go in the boats. The stores and spare ammunition should come in later, after the landing is effected. For the rapid and safe landing of these articles the steam launches are available. Boats to carry the companies ashore should be as light as possible, for quick transportation and for getting in close to the shore. I would exclude from these boats all other articles than the entrenching tools.

The signals used should be of the simplest, and as few as possible. The boat carrying the commanding officer of each battalion should have a staff and a set of signals to be used if necessary. Each boat should be provided with answering pennant and tactical signal book. Enough signal men should be landed to allow two for each battalion and four for the brigade commander. In landing to operate near the squadron we have found that but few signals are necessary, as for instance:

No. 1 exhibited means, Forward.

No. 2 exhibited means, Skirmishers advance, land, and deploy.

No. 3 exhibited means, Main body land.

No. 4 exhibited means, Artillery commence firing.

No. 5 exhibited means, Artillery land.

No. 6 exhibited means, Reserve land.

All other signaling was done by the wig-wag flag. I see no reason why our men should not be instructed in erecting telegraphic communication. Such knowledge and material for its use might prove of great service.

It is of the greatest importance, when action takes place near the landing where there is no cover, that after the advance line is maintained the brigade should be protected by entrenching, particularly in event of retreat. To effect this in any reasonable manner or time requires, we have found, the efforts of the entire force left. The number of pioneers landed is only sufficient to form, perhaps, the leaders for this work. They should for this reason go in the boats containing the companies to which they belong, and be prepared to

carry, where needed, the entrenching tools brought on shore. When landed, they should remain at their boats till these implements are landed, and under the direction of the beach master transport them where they are required for use. The essayist, in the combination of the units (ships' battalions) to make up a brigade, cuts down the number of pioneers as landed with the ships' battalions. This I think a mistake, on account of the work that might have to be done by them. To be of any practical use they must be of sufficient number. At all events, whatever the number of pioneers, signal men, or whatever else, that number should land for that particular purpose, and not be liable to change at the landing.

Stores and spare ammunition to be landed can be handled by the boat-keepers assisted by the company cooks, as far as putting them ashore is concerned. After this, for transportation from the place of landing a working party would have to be detailed from the battalions, so many from each company. If the action is to take place near the place of landing, no stores should be landed till the landing is effected and sure of being maintained. If at any distance from the landing, the stores should be carried to the means of transportation by the working parties detailed as I have said. The question of maintaining supply is a vital one, and a neglect of this would cause failure.

We have these facts to deal with if we consider the Naval Brigade without co-operation. The squadron must be left efficient, capable of moving and of fighting. We have so many men ashore for the purpose of the expedition: with these we must make the best disposition possible under the circumstances. The supply train must be sufficiently guarded, and the men to handle material must be available. The commanding officer of the brigade will decide the best means of doing this, the means depending upon the circumstances of the case he has in hand. Cooks should be detailed, one for each company of infantry and one for each platoon of artillery, this force increased by a detail of one assistant cook from each company of infantry and platoon of artillery when in camp or bivouac. These cooks, on the march, should be with the quartermaster and commissary, to act as a guard and assist in handling stores.

As far as the infantry is concerned, I see no reason for any change from the army tactics. The evolutions employed should be of the simplest character, and the method of deploying by numbers recommends itself as leaving an entire front for the main body after the skirmish line has been thrown out. The simpler company movements of forming column, and from column forming line, are quickly acquired by the sailorman, and make up with the skirmish formations about all that is necessary. In fact, the company commanders will be depended upon to a very great extent, the battalion commander giving them directions as to what is to be done.

The bivouac of the brigade (Plate III.) is a system well planned, excepting that all the artillery is parked to the rear. The main body certainly should not be without the Gatling guns distributed along the line of the most probable points of attack. I would place the Gatling with the grand guard, the rallying point of the outposts. Even with the front towards an enemy, I believe in a concave formation for the main body in bivouac, as a means of protecting the

[illegible] Naval Engag[illegible]

[illegible]

[illegible] practice of every army [illegible] in favor of my prop[illegible] so many warmly a[illegible] more difficult of attainmen[illegible] especially after bei[illegible] effect upon an adversa[illegible] in the enemy's line[illegible] about him; 25 to 30 m[illegible] never is the time; but 30 men [illegible] companies to his right and le[illegible] captain thinks the chance hazardo[illegible] hesitate: when the battali[illegible] scene it is too late, the ene[illegible] chance is gone, and with it, perhaps, t[illegible]

[illegible] varies considerably in different armi[illegible] in the German army [illegible] in our own army. Mr. Hutchi[illegible] I propose [illegible] men per officer, a lieutenant to co[illegible] associated with him. These officers should be tak[illegible] the men come from: I thus have the companies o[illegible] own division officers, with whom they are familiar as well [illegible] known.

[illegible] in a vessel of the Atlanta class, [illegible] men, and two guns and limbers, [illegible] and carriers, 2 stretchermen, 2 sig[illegible] complement of 242 men, not includ[illegible] making a total of 18[illegible] necessary in addition, a[illegible]

the 5 men to run the steam launch, which would generally tow the boats. This makes a grand total of 205 or 207 men and 9 officers. Even allowing that the complement was full (a thing which every naval officer knows is rarely the case), my experience proves that such a force *cannot* be landed and leave the ship effective, and in this opinion I am backed by every officer attached to the Atlanta to whom I have spoken on the subject.

I propose to land from the Atlanta 1 company of blue jackets (73 men), 1 gun and its limber (24 men and 12 G.), 1 platoon of marines and 2 sergeants (34), 4 pioneers, 2 signalmen, 2 stretchermen, 1 bagman or apothecary, 12 boat keepers, 5 launch's crew, with 3 company officers, 1 artillery officer, 1 marine officer, 1 engineer officer to command the pioneers: to land more men would render the ship inefficient. I have a total of 158 men and 6 officers as against 205 men and 9 officers mentioned in the essay.

Major W. R. LIVERMORE, Corps of Engineers, U. S. A.—In referring to my remarks at the War College this morning, Mr. Dillingham was correct in thinking that I said that in the manœuvres planned for to-morrow,* it was not expected that the troops would adhere to the formations and commands laid down in Tactics. I referred to Upton's Tactics, but did not mean to imply that Tactics should be thrown aside in the fighting formations. On the contrary, I think that is when Tactics are most needed; and it is one of the fundamental principles of the system I would like to see adopted, that it should afford a language as applicable to the irregular groups of a modern fight as to the rigid masses and lines of the past. It is quite generally admitted in the Army that Upton's Tactics are not applicable to a modern fight, and the illustrious author of that system was fully aware of its imperfections, and was at the time of his death preparing to correct them.

With regard to the company column, we must remember that it is the successor of the battalion column of former days and not of the old companies; and the same principle that reduced the battle unit from 1000 to 250 men will soon reduce it again to about 60 or 80, and with our present organization of 100 men we can count on about that number in rank. It is desirable to organize the regiments with 12 companies, not so much for the sake of having three battalions to a regiment as for the sake of having four companies to a battalion, and in time of war it would be well to add another battalion so as to make 16 companies in the regiment.

It would be well also to group the higher and lower units in fours, and all European nations are coming to this conclusion. Napoleon said that no man should be required to command more than four others. It is simple and better to describe all tactical movements on the supposition that each unit is divided into four fractions, and these descriptions will answer for any number that may be presented.

Troops are disposed upon an area having two dimensions—length breadth; and the simplest manner of dividing a unit is to separate the fr and rear and divide each into the right and left fractions.

* This refers to the landing of the Naval Brigade of the North Atlantic Squadron on Coaster's Harbor Island.—*Editor*.

In advancing to action under distant fire there is no formation better than the square of 16 men. There should be sufficient interval in every direction between the men to enable them to move and face without interfering with each other, and the groups should be separated by sufficient interval to avoid heavy loss from hostile fire. It appears to me from this evening's discussion that this grouping of units is that best adapted to the Naval Brigade, as well as to the requirements of the Army.

All foreign armies are simplifying their tactics so as to reduce the number of evolutions to a minimum, and to devote most of their attention to applied tactics to teach the troops how to take advantage of topography.

Infantry so fractioned and grouped is better disposed for the irregular operations of modern warfare. But whatever system may be adopted in the Army, it will be so flexible as to be fully applicable to any other grouping that may be required from time to time, for the organizations will seldom be complete, and the fractions of several units will be often united.

In organizing the Naval Brigade, the important principle is to preserve the hierarchy as far as possible, and I think that this should be adapted to the requirements of the ships, and that any system that may be adopted by the Army will be found to be applicable.

Commander C. F. GOODRICH.—*Mr. Chairman and Gentlemen*:—I regard the essay as a paper of great value to naval officers. When it is considered that the conditions of the competition limited the writer to 40 pages of the "Proceedings of the Naval Institute," it is remarkable that so much ground is covered, and covered so well.

Having been associated with Lieutenant-Commander Hutchins, and knowing his habit of mind, which is so well displayed in the essay, I feel it incumbent on me, in his absence, to meet some of the criticisms which have been passed upon his article, although I speak entirely without authority. The subject of the essay covers so many points that it would be remarkable if some were not overlooked, or if in some things the writer was not of our way of thinking.

In regard to Commander Hoff's criticism of the formation for landing, it is very true that the boats may not approach in line, and hence the exact form prescribed by the essayist cannot be carried out. But what of that? It is precisely what is to be expected in action, and our plan must be made for meeting such an emergency on the spot. This will be true in regard to any method of formation which may be proposed. Absolute regularity of formation and coincidence of arrival at the beach, however desirable, may not be obtained, but we should strive for them, and if not successful, do the best we can under the conditions that exist at the time of landing.

I differ with Lieutenant Dillingham in regard to the detail of officers to the command of battalions. I am very jealous of maintaining the prerogative of the executive officer. I believe that this does much to preserve a sound *esprit de corps*, and I do not think the executive of ships will be willing to resign important commands. It has always been the rule in the service that the executive officer should command expeditions sent on detached service.

Furthermore, I do not think that the men would have as much confidence in a strange commander as with one under whom they habitually serve, although the strange commander might, perhaps, be the better man.

Lieutenant Dillingham wants the material for landing the Naval Brigade on this coast kept at one point where the vessels could rendezvous from time to time for exercise. I cannot approve the custom of confining such operations to one place. On the contrary, I think that every ship should be so provided and her landing party so organized that she could, on leaving this squadron, for instance, go abroad and find her proper sphere of usefulness in any other squadron which she should join. In other words, I think that the equipment and organization of landing parties everywhere should be the same.

If I understood Lieutenant Dillingham rightly, I think him in error in diminishing the number of ammunition carriers; I think the essayist has, possibly, not provided ammunition carriers enough. The large expenditure of ammunition, due to the introduction of magazine rifles, makes the rapid and sufficient supply of ammunition of very great importance. Although the number of rounds now carried is large, they will be shot off so quickly as to leave the troops in the front without ammunition very much more speedily than was the case with the old-fashioned arm. Moreover, if any considerable distance is to be covered, it will be found impossible to count upon the possession of the regulation 80 rounds of ammunition upon the part of every man, for it is well known that armies on the march relieve themselves of weight whenever possible. Indeed, their route may often be traced by the cartridges which have been dropped by the soldiers in order to lighten their equipment.

Lieutenant Dillingham's remarks upon the function of the steam launch in this connection are admirable. They are based on experience, and they commend themselves to all interested in the problem.

I think this is a good opportunity to speak of the very indifferent system of signals by the use of bunting to which the Navy has been tied for so many years. The flags themselves, and the code for which they are utilized, have always been unsatisfactory, as it is barely possible to make out a signal at any distance except under rarely peculiar and favorable circumstances.

In conclusion, I wish to express my deep appreciation of the terseness of Lieutenant-Commander Hutchins' style and of the practicality of his suggestions. The latter exhibit a happy combination of study and experience. Indeed, the whole essay commands our admiration, since by the wording of the subject proposed it was made to cover almost the entire art of war.

Commander BAINBRIDGE-HOFF.—I think our signals are better than Commander Goodrich allows. We have fewer flags than any other nations, and our naked masts permit a four-flag signal to be as easily read as a three-flag, provided the flags are supplied of slightly smaller dimensions than now. Our Army and Navy Code, with its Morse alphabet as now adopted, is as good as any, and our signalmen can be put on the electric key. The now used in some of our ships in this station is better [illegible] tore

lamp, as we can make more symbols from the nature of flash given to the eye by the Ortman shutter. The signal book has been thoroughly overhauled, and the new drill book, taking the place of the old tactical signal book, has passed the inspection of several boards—Mr. Hutchins being on one of them.

Lieutenant-Commander C. T. HUTCHINS.—*Mr. Chairman and Gentlemen*:—If there is any one subject upon which naval officers are most prone to disagree, it is the organization and detail of the Naval Brigade. The discussions of the essay by the able officers who have taken part show, however, that the subject is one of vital importance to the service.

I have quite expected criticism of my essay on certain points, more particularly on the size of the infantry company and the deploying of skirmishers by numbers. I believe that the latter has been given up by European infantry tacticians, who strive for the individual deployment of skirmishers in a fan shape; still, I do not know that there is anything better for the seaman, who does not have many opportunities for skirmish drill on shore.

In reply to some of the criticisms:—

In the remarks of Commander Hoff on my "order before landing" he suggests to place the boats in columns to be towed by steam launches, in which formation they lead in "to land," casting off the tow and forming groups, all of which is done under fire. When we consider how difficult it will be to control the varying speeds of these columns, not knowing the proper moment to cast off the tow, the depth of water, and grounding of steam launches, there is every reason why boats should advance and land in line.

One shot into a steam launch might disable her, the boats overrun each other, there is confusion, and the result may be predicted.

In the "Order before landing," the signal is made to "land," when the boats get to the beach, as soon as possible; the skirmishers having already landed, the artillery clearing the landing place by a cross fire from the flanks.

The line formation presents the least exposure to the enemy's shot, and I fail to see why boats under fire should be huddled together in groups, with the object for grouping wanting, at the same time making a good target for the enemy and interfering with each other's movements.

We are all familiar with the difficulties encountered in the disembarkation and landing of the brigade. At night there may be occasions, when the electric lights are used, to form the boats in the shape of a triangle, the boats advancing in the dark zones, the point of the triangle leading. Even in this formation there will be a time when the boats must form line in order to find room to land on the beach.

The nearer we can come to the simultaneous arrival of the boats at the beach, the more certain we are of obtaining a foothold; which is not obtained by the advance of boats by columns and forming groups. Boats should be towed in toward the beach by tugs or steam launches, but they should cast off the tow and form the "order before landing" before the advance is made.

Commander Hoff says that the steam launches should carry Gatlings. I

have it from the best of authority that "in Europe the Gatling is completely played out, and it should be in this country." Steam launches would be better armed with the 1-pounder Hotchkiss, the best all-around gun now in use.

Like Commander Hoff, I am in favor of placing the artillery boats where most needed, and this I believe to be on the flanks, where they will also interfere less with the command and the direction of the infantry boats. You cannot obtain the maximum cross-fire on the shore with the artillery in any other place, and to attain the greatest effect artillery boats must be placed in échelon formation.

Lieutenant Dillingham takes issue with me in my combination of the different ships' battalions, and says: "Under these [my] conditions the battalions of the different vessels land, and after landing the brigade is formed." I am sorry that I did not make myself clear on this point, for by reference to page 330 of the essay, under the head of Disembarkation and Landing of the Naval Brigade, I state that each company of infantry (seamen) lands in the two ship's boats belonging to the division, and that these two boats always keep together, and *must take the same relative position in the order before landing as the company holds in the brigade when formed on the beach.*

The object of the "order before landing" is to organize the brigade in the boats before it is landed, each company being in its two boats and opposite to the place it is to occupy in the line of battle on shore. Where the company lands it forms, and I have never heard of, nor much less have I ever seen, a landing made in any other way.

Again, Lieutenant Dillingham says: "There is no division aboard any ship in commission in our service, and less liable to be one in the future, on account of the less number of men required to man a modern gun, that can supply an infantry company of forty-six men, unless we except the powder division or the engineer's division." For his information I would state that the Lancaster has two gun divisions with each one containing more than 50 men, and that the forward and after pivots have together 50 men, the officer in charge of these guns to go with the company. When I left the Lancaster, some three years ago, her first division had 56 men, and the second division about the same number. I am not aware that her complement has been cut down. The Marion's second division has more than 50 men in it, and I take it for granted that every ship of her class, seven of them, has the same. There is no reason why nearly every small ship in the service should not have a gun division of 46 men, and every large one two gun divisions, with 46 men or more to each. The modern idea in the navies of Europe is to have an officer to each gun of any size on shipboard, ammunition having become so expensive that the firing with great guns must be kept under control. Why have small divisions under inexperienced officers, when they can be combined under an experienced one? The smaller vessels are capable of landing a company of infantry composed of 46 men; they would hardly be able to land two companies of 36 men each. Taking into consideration all classes of vessels, and being able to form one company of infantry from two artillery companies, I believe 46 men to be the most suitable number for the needs of the Naval Brigade. I am

aware that officers may not be able at all times to have command of the same men in the brigade organization, but it should be the object sought after. Modern tacticians divide an infantry company into sections, and the formation of the company and its movement by either flank remain to be brought out in a future tactics. A fairly well drilled man with the Lee magazine gun can fire away 80 rounds of ammunition in five minutes: could modern thought doubt for an instant the necessity of ammunition passers and carriers? Lieutenant Dillingham suggests that file closers be used to pass ammunition. File closers in the modern fighting line direct the firing of sections of the company; they are the most important men in the company, and must give all their attention to fire discipline. I will admit they are of no use for parades, but my belief is that two file closers are *not* enough for a company, judging from the company organizations of European armies.

Lieutenant Dillingham sees "no good reason why the skirmish lines should be in boats in advance of the main column." The skirmishers in advance (two boats' length) of the centre of the main body in light, fast boats, are opposite to a point where they are to land and deploy, or deploy by boat and land. The flanks of the main body are protected by the artillery, and probably by several ships of the squadron; therefore, in only very exceptional cases should the deployment of skirmishers be from the flanks. It would be a violation of a principle in tactics to attempt to cover a front of a line of battle by the deploying of skirmishers from its flanks, as suggested by Lieutenant Dillingham. It might do for the pomp of war, but it does not belong to any school of tactics. Lieutenant Dillingham also says, "it might be necessary for the artillery to be put in advance of the line" of battle. This would be a violation of a principle in the art of war, not to bring guns into action without infantry supports in advance.

I cannot agree with Lieutenant Dillingham in the use he makes of the Gatling gun. It is well known that in European armies the Gatling has been thrown out of service—in fact, the bullet-firing gun is practically abandoned for military use. England, like ourselves, being behind the times, is the only country in Europe that has bullet-firing guns incorporated in its military armament. All the other great powers of Europe have no bullet-firing guns either in their military or naval outfit, Italy excepted. In my essay I class the Gatling last in its usefulness for the Naval Brigade, and it is about in keeping with the Springfield rifle. There may be occasions when it would be advisable to have with the grand guard a few pieces of artillery—for instance, one or two 1-pounder Hotchkiss guns; but I am opposed to the mixing up of artillery and infantry in the bivouac of the Naval Brigade; both arms have their proper and separate functions to perform, and it might lead to confusion when forming line of battle in the event of an attack. In the bivouac the formation will depend on the nature of the ground, roads, etc. The inner line or main body, *with level ground*, should be somewhat concave toward enemy, but the outer line, pickets and sentries should be convex.

Lieutenant Clason takes issue with me on the size of the company of infantry, and suggests 73 men, his reasons being, "To have such small com-

panies (46 men) is contrary to the universal practice of every army," etc. I am aware that small companies are quite unknown in armies that have plenty of men; but I hold that the small company suits the purposes of the Naval Brigade, and that 40 files in a company are quite as common as 64 files, his own number; and the combination of the artillery companies is not possible with this number (64) of men to a company.

Again, Lieutenant Clason states that "205 or 207 men and 9 officers can *not* be landed from the Atlanta and leave the ship effective." Effective for what? Certainly the ship could bank fires and fight most of her guns, or keep under way and fight some of the heavier ones.

To quote from the essay: "The circumstances governing the work required of the ship during the absence of the battalion would decide if all the force or a certain number of companies should be landed."

With regard to "the 12 or 14 boat-keepers, and 5 men to run the steam launch," of which Lieutenant Clason claims I have "taken no account"—in extreme cases boat-keepers would have to be reduced to a minimum.

Admitting that men in the service are as efficient as the special service men at the Naval Academy, I fail to see why 5 men should be required to run a steam launch under the circumstances. We have been running 12 and 13 steam launches at the Naval Academy, some of them 40 feet long, and a Herreshoff 56 feet long, for the past two years or more, with 2 men all told to the former and never more than 3 men to the latter. "The 12 or 14 boat-keepers" can be cut down to 7 men. Now, one more word about "leaving the Atlanta effective." If you wish to fight her in the absence of the landing party, land but one company of infantry and one piece of artillery; but when the time comes to land all the battalion, I am convinced, notwithstanding what Lieutenant Clason says, that the Atlanta can do all that I have claimed. As an instance of what can be done in the engine and fire rooms of a ship, where the Atlanta would have to draw men from to work her guns in an emergency, I give the following incident: The monitor Lehigh was lying at Port Royal, S. C., when we were ordered to proceed up the Savannah River, where we anchored off Fort Jackson and hauled fires. The third night after anchoring, and by the time I could get on deck and take in the situation, the ship had dragged three anchors about one-eighth of a mile, a freshet having come down the river sweeping everything before it. With the turn of the tide the ship dragged again and fetched up on some heavy piles—obstructions in the river—the ship's overhang resting on them. It was now a question of which would win, tide or furnaces; for on the turn of the tide again the overhang would hang on the piles, and probably separate from the hull of the ship. But one hour and forty minutes remained to get up steam, with no engineer, two machinists—one a stranger—and two marines borrowed from another vessel—the marines had once worked in the fire room. All the Lehigh's firemen had been sent down the river to help another vessel of the fleet. Fires were started and steam got up, and in less than two hours the Lehigh was anchored out in the stream, with a cost to the Government of little over one barrel of oil and a few bulkheads used for the fires, with two machinists, two marines,

and four deck hands to pass coal, all told, in the engine and fire rooms to do the work. All this could have been done, and probably better, in war times. I still must claim that the Atlanta can and is quite able to-morrow, should the opportunity present itself, to do what I stated she could do in my essay, and leaving 82 men and 13 officers—a total of 95—on board. I do not claim the organization I have given in the essay for the Atlanta to be her habitual one, I only desired to illustrate what landing force a ship can organize when a large number of men are wanted. Had one-third of the men been landed from the English fleet at Alexandria, Egypt, in 1882, that city would have been saved from pillage.

The CHAIRMAN.—The Naval Brigade, its organization, equipment, etc., is still in an unsatisfactory condition, not so much as to the actual organization of the brigade itself perhaps, but rather as to how the men forming the companies of infantry of each ship are to be selected. The question really begins with the organization of the ship's company as the basis of all other organizations. Our thoughts on this subject are in a state of solution, as it were, and it is to be hoped that by means of these discussions they may crystallize into clear ideas, not only on this but on all other subjects of a kindred nature.

Our sailors will be called upon in future, as they have been in the past, to land as a military organization for military operations on shore. In this respect we do not differ from other navies. The English, French, and Italian navies are constantly sending their sailors on shore to co-operate with troops in belligerent movements—the English in Egypt, the French in China, the Italians in Africa. Our Naval Brigade should be so organized as to enable it to operate on shore with the utmost efficiency, and at the same time with the least inconvenience to the ships of the squadron. Moreover, the brigade should be landed frequently.

"It is a well known fact," says a recent writer on military tactics, "that for the first three years of the War of the Rebellion, there were more lives lost and property destroyed from mere ignorance than from any other cause. The object of all military training should be to prepare men for war. Drill, as a means of teaching discipline, as well as preliminary field movements, etc., can be taught anywhere; but the underlying elements on which the art of war is founded can be learned only by practical experience." These remarks apply with equal force to us. But, to drill with the best results, our organization should be as nearly perfect as it is possible for us to make it.

I believe I fully express the sentiments of the meeting in returning thanks to Lieutenant Hutchins for his excellent paper.

## WASHINGTON BRANCH,

October 17, 1887.

Commander A. D. Brown, U. S. N., in the Chair.

Ensign W. L. Rodgers.—*Mr. Chairman and Gentlemen*:—In reading Mr. Hutchins' essay, my first thought was of the entire practicability of all its ideas, so that, with one exception, my remarks must be confined to details.

I think a change for the better might be made in the titles assigned to the officers of the brigade. The army titles appearing in the printed ship's battalion bills are objectionable, because the Navy Regulations assimilate them with certain naval ranks not usually held by the brigade officers, and when to a young officer attached to a small force we give the mouth-filling title of quartermaster-general or adjutant-general, it makes him and his office ridiculous. I think we may find a fitting military title for the brigade commander in the obsolete army title of brigadier. For the commanding officers we might form titles derived from the French "chef d'escadron," and call them battalion chiefs, battery chiefs and company chiefs. For the officers on the staff expressive titles would be brigade adjutant, battalion quartermaster, battery surgeon, etc.

In assigning the brigade to boats, Mr. Hutchins distributes the marines as sitters in boats pulled by sailors. This seems objectionable, whether the marines are distributed among the sailor companies or whether they have their own boats pulled by extra seamen; for in one case the marines are disorganized and in the other the non-combatants are increased. In the North Atlantic Squadron the marines row their own boats, and when we think that any landsman can soon learn to pull a good oar, and that landing will rarely be made in bad weather or in heavy surf, this plan seems preferable.

I now come to the only point upon which I strongly disagree with Mr. Hutchins. In the matter of tactics he speaks approvingly of Upton's deployment of the skirmish line by numbers; I think this idea cannot be too strongly deprecated. We must recollect that although this system is now twenty years old it has never been employed in battle, and that the experiences of the recent great European wars have been so unfavorable to formations of such a nature that its author was engaged upon a new tactics at the time of his death.

The necessities of modern fire tactics require the strictest control of the fire on the part of officers and leaders of all ranks, which can only be obtained by always associating the same officers and men together, and so exercising them in manœuvres and firing. This is particularly important in the case of the small squads of 10 to 15 men. It has also been found necessary to give to the commander of any given part of the fighting line the supports and reserves required to carry through his part of the action; so that commands should be organized in depth rather than in length. In the skirmish line by numbers these rules are violated; adjacent men in the line are unacquainted with each other, and the officers of the line are chosen by an arbitrary rule of odd and even. When the supporting lines are advanced they start in the same dis-

organized condition and without any connection with each other, so that mutual support amounts to nothing.

In the armies of continental Europe, each command forms its own firing line with supports and reserves, and the ultimate units on the firing line are groups of ten or fifteen men, under leaders to whom they are known and by whom they are always commanded. A German company (250 men) is divided into three divisions. In the development of the line of battle, one division is thrown forward to form the skirmish line, and as the enemy's fire becomes more and more effective the division subdivides until the skirmish line is formed, but each "group" (10–15 men) remains under the strict direction of its leader. As the line needs reinforcements, the men of each group on the firing line close their intervals and complete groups from the supporting lines are pushed into the gaps thus formed.

Upton's deployment of skirmishers by the flank, however, can be readily employed in such a way as to fulfill all requirements. If the company of our landing force is organized as suggested in the Ordnance Instructions, the platoon of 16 men should be regarded as the smallest tactical unit, and the men in it should always be the same, and should be constantly exercised in every kind of collective firing. If the companies are grouped together in divisions of two companies each, under the senior company chief, and the divisions in threes under a battalion chief, we should have a battalion of the size of the German company.

To form a fighting line with one or more battalions, we might begin with the battalions in line with each battalion in double column of fours, or massed in column of divisions, and advance until the enemy's fire begins to tell. A division would then advance to form the skirmish line, followed at 300 yards interval by a second division as support, with the third at a similar interval as reserve. The fighting line on beginning its advance, say at 2500 yards from good artillery, should separate into platoons, and when at a distance of some 2000 yards the platoons should deploy as they advance, according to Upton's tactics, but each platoon should look to its leader for all directions in regard to movements and firing. If the line is boldly pushed forward, it may not need reinforcement until between 600 and 700 yards of the enemy, when the losses of the line and a contraction of each platoon towards its centre will afford intervals into which the organized groups of the support may be thrown. The importance of preserving the organization of the groups and of teaching stragglers to attach themselves to the nearest group leader is considered of the highest in all military training abroad. In this way, all reinforcements should be absorbed into the firing line, and I think that by torturing Upton's deployment by the flank only a little, we shall find it equal to our requirements.

Lieutenant C. G. CALKINS:—It is always very easy to criticise an essay, and does not always require technical knowledge on the part of the critics. I suppose that is one reason why any one who joins the critics is sure to find himself in the majority. Mr. Hutchins has arranged his paper in a very methodical manner, and it is very easy to follow. A great deal of it is very easy to

agree with because it is what we have been taught and what we have tried to carry out a great while, without having any great amount of success; but I think the criticism just made by Mr. Rodgers, about the use of skirmishers by numbers instead of by the flank, a very sound one. For instance, extending the line of skirmishers to cover the front of the battalion until the enemy be flanked can be much better managed by sending detachments, companies or half companies, and keeping them under their own officers as far as possible, although it is not absolutely possible to keep a skirmish line under the control of any given officers.

I think Mr. Hutchins gives too much importance to the formation or alignment of boats. It is a mistake spending a great deal of time trying to arrange boats in line and make a formation which is apt to be drifted out of shape before completed, and then advance in that formation against the enemy.

As a general thing, the fire from small boats advancing against an enemy is thrown away. Possibly some long boats with Hotchkiss guns in their bows might do something towards clearing a beach, but the fire from howitzers and Gatlings from pulling boats is a mere waste of powder, and the fire of the men also is wasted. I think the landing must be made either where the enemy is not present or where a beach can be swept by artillery firing along a sandspit, or where the water on both sides allows the ship to get a raking fire on the beach. After they get ashore, Mr. Hutchins lays down the order of march very carefully, and it is entitled to a good deal of consideration.

The science of war is something that every one is not called upon to understand. I heard a French officer, who had been in a little engagement in Formosa, who had something to say on the science of war. He said they came face to face with a lot of Chinamen who were huddled about on the slope of a hill among the bushes, on the other side of a paddy field. The men landed from the ships, were drawn up, and wanted to get across and get at those Chinamen. He said, "We didn't know how to do it, and finally were obliged to retreat. We killed some of the Chinamen, but in getting off we capsized a boat, lost a Hotchkiss gun and a few men, and in fact, summed up in a few words, we were well thrashed simply because we didn't know enough of tactics to advance over that paddy field."

When we follow the error that has always pervaded our drill books of tactics, and omit all reference to the enemy in drill formation exercises on shore, we are laying ourselves open to exactly the same kind of accidents. Of course tactics is nothing else but handling men in the presence of an enemy, and the drill book which gives a formation that would be impossible in the presence of an enemy is making a very dangerous error. It is only necessary to take up the field exercise books of any foreign army and see that they begin at once in the presence of the enemy. In the German army they take the men almost before they know the manual of arms and exercise them in changing ground, in selecting cover, in making advances, etc., giving them the most active instruction of this kind in the first six months of their drill before they pass their first inspection. With Mr. Hutchins, I think that we had better not land at all for service until we can have some instruction in the art of handling men in the presence of an enemy, and get some experience in that art.

The Chairman:—In that connection we might recall the expedition to Formosa in 1867, when Lieutenant-Commander Mackenzie was killed. We had plenty of men there, but could not do anything on account of the country being so rough and densely covered with undergrowth. The question then comes right back to what Mr. Calkins has said, whether it is advisable to attempt anything of the kind. It seems to me, in this question of the Naval Brigade, that we are not very apt to meet the enemy as it is laid down in the essay. In the first place, we are not apt to have such a large number of men that we could safely go out and camp a long distance from the ships. In the instances which have arisen in the past, such as those at Panama and at Alexandria, after landing we were not far away from the ships. Until we get a very much larger navy than we have now we are not likely to have the number of men that Mr. Hutchins has put down in his essay.

Ensign Rodgers:—I have recently read of the expedition in which Lieutenant-Commander Mackenzie was killed. The trouble was that this party was sent down to avenge an American seaman's death, and they had no tactical object before them. The result was they lost a great many men by sunstroke; the country was very difficult, exactly similar to that where Lord Wolseley used a naval brigade in Ashantee. He (Lord Wolseley) had a force of three or four hundred men from the navy before the army arrived. He knew exactly what he wanted to do with them, and he used them so they had the utmost effect on the future campaign. He beat the savages very easily; burnt their villages and destroyed their crops, which exercised a great moral effect in the campaign which followed. He was enabled to do this because he knew how to employ these sailors, whereas our people out in Formosa did not.

Lieutenant Schroeder:—If I recollect aright, the cause of Mackenzie's death was from charging into the bushes where the enemy who shot him were concealed, which is likely to occur to any one.

Lieutenant Calkins:—I do not think the enemy were seen more than once or twice in the ten days. The brush was very heavy, and it was almost impossible for the men to keep any formation in the shape of a skirmish line, if you choose to call it so; every man had to be for himself, fighting behind trees and that sort of thing.

The Chairman:—Then the point seems to me to be whether under these circumstances it is judicious to attempt anything of the kind.

Ensign Rodgers:—I think the reason that Lord Wolseley did so much was because he knew just what he wanted; yet he used just the same material, the Naval Brigade. The operations lasted only a few days. There was no army in the country, it had not come. And the cases were precisely similar except that one started without any clear idea of what was to be done, and the other knew perfectly what was to be done.

Lieutenant Calkins:—It seems to me the same principle might possibly have applied in Corea. If the marines had been landed in a certain way, the Coreans must have abandoned their forts even before the Palos went past them.

Lieutenant Schroeder:—The Palos did not go beyond the forts during the landing. I was present in that campaign. The Palos and Monocacy ran the

gauntlet of the forts and came back, and ten days afterwards the landing was made from below the forts.

The Chairman :—The force was at no time at any great distance from the supports, was it?

Lieutenant Schroeder :—No. We were out of gunshot, but not very far. We were two nights and three days ashore. The Naval Brigade landed about 650 men. When we captured the citadel, a large number of the Coreans that were killed were chiefs of greater or less importance, which had some ultimate effect on the campaign, as Mr. Rodgers was saying of Lord Wolseley striking a blow that would be felt for a long time. And touching that expedition also I want to call attention to what Mr. Hutchins says about marines. On that occasion we practised our marines in pulling boats beforehand, and they pulled themselves ashore.

Ensign Rodgers :—I think two-thirds of the force of the ships were ashore?

Lieutenant Schroeder :—About 650 in all. I suppose the fleet numbered thirteen or fourteen hundred.

Ensign Rodgers :—Then the covering ships, the Monocacy and Palos, did not land any men?

Lieutenant Schroeder :—No :—at least not till the attack was over, I think.

Lieutenant Calkins :—I would like to know if the object was to kill the Coreans, or if the object was to occupy the fort?

Ensign Rodgers :—Well, the reports of that action say they needed half the force of infantry to keep back the Coreans who were trying to rescue those captured.

Lieutenant Schroeder :—Part of the force was used for that—about two companies. Some of the artillery was posted on the hill, after capturing it, to check the advance of a large body of Coreans, said to be 7000 at the time, though probably not nearly so large. We had the marines and one company of blue jackets on that outpost hill, I think. A good many of the Coreans escaped as we advanced, but about 250 were killed in storming the citadel.

Lieutenant-Commander STOCKTON :—I would like to say a few words upon a subject that may appear at first sight somewhat foreign to the essay; but as it relates to its practical effect upon the service, I will not hesitate to do so.

From a somewhat hasty perusal of this paper it seems to me a sensibly written one, likely to be of practical service if its ideas are put into effect.

The essay is the result of the yearly offer of prizes by the Naval Institute, which have of late years, in subject matter, become more practical, and hence more likely to be of every-day importance to us. The subjects proposed of "Torpedoes," "Naval Brigade," "Changes Incident to the New Ships," etc., etc., all bear directly upon the daily training of our men and the proper use and manipulation of our fighting material.

But there is a link missing between the preparation and publication of these timely papers and their communication, duly authorized and shaped, to the service at large. At present our drill manuals, properly authorized, are very scanty in number, obsolete in matter, and confined almost entirely to one bureau.

When I speak of the drill manuals I do not refer to the many fugitive pamphlets, papers, and books issued in a semi-official manner from various bureaux, often at variance one with the other, and all lacking that stamp of definite and final authority which will allow us to use them on board ship as established service manuals. The result, however, of these various professional papers, reports of boards, and prize essays, issued with the very best and most laudable of intentions to meet the great want of modern and freshly revised drill books, is, to say the least, confusing.

Some one office or person or bureau should have the whole matter in charge, and by giving us authorized and appropriate drills, enable the service to have uniformity in its routine and its various exercises and evolutions. There is no professional and actual head of the Navy who directly controls the personnel of the service, and to whom the Secretary can go as the person responsible for the efficiency, training, and discipline of the officers and men. The results of the various inspections, imperfect as they are, are lost; no present stimulus of consequence occurs from them, no future permanent improvement can be traced to them.

Lieutenant RUSH.—Lieutenant-Commander Hutchins has given us the most valuable paper upon the subject of the Naval Brigade that has yet appeared. In looking over his essay, one or two points have suggested themselves to me, about which I should like to say a few words.

First, as to the matter of organization. The Naval Brigade being composed of the united battalions of two or more vessels, the battalion becomes the basis upon which the brigade is formed, and the efficient organization of the former means, to a great extent, the successful formation of the latter. I take up, therefore, for consideration the question of the organization of the ship's battalion. Mr. Hutchins has given us an excellent sample case in the Atlanta's landing party, and I think he has worked out the organization most admirably, but on one point I would suggest a change, and this is in the matter of primary organization. In stationing the ship's company in station, quarter, and boat bills, I suggest doing it on the basis of the battalion organization; or, to put it more accurately, having divided the ship's company into two watches about equal in strength, intelligence, and activity, make out the other station bills with the battalion organization constantly in view. I am aware that this plan of organization is a radical departure from old time custom, which regards the growing importance of the Naval Brigade as of doubtful expediency, and even our prize essayist himself, I see, stamps such a measure as "probably resulting in disaster." But with due regard for the weight of opposite opinion, I am still of the belief that the organization of the ship's company in its various station bills upon a qualified battalion basis (if I may so express myself) will tend greatly to the solution of one of the most difficult problems which our first lieutenants have to meet, viz., the question how to organize their various formations so that comrades may be kept together, whether on board ship, embarked in boats, or landed on shore, the same men always together and under all circumstances under their own officers; furthermore, I

hold that the station bills so arranged will in nowise conflict with the proper organization of the ship's batteries, boats, or fighting establishment, but, on the contrary, will render the "parent ship" more efficient because better organized. To elaborate fully this scheme of organization would be beyond the limits of this discussion, but I think the question one worthy of careful examination and argument. That it will meet much opposition I have no doubt, but that the plan, or something similar, will eventually be adopted, I think highly probable.

In regard to equipment and outfit, Mr. Hutchins has covered the ground so exhaustively that I think there is little left to be said. I would add, however, a few items of comment. Abolish the cutlass and pistol, and substitute the rifle, except in the first six numbers of the artillery sections, the pioneers, the ammunition party, and the hospital service, which arm with revolvers. Reduce the number of men in the artillery sections (light guns) to twelve and a quarter gunner. Do not abolish the drum, but keep it with the bugle as the best possible field music. Do not entirely put the 12-pounder howitzer out of commission, but keep an odd one on board of each ship for occasional service; loaded with shrapnel or canister against a mob, or for close work, as in street fighting, it is second in value to the Gatling, and superior for destructive effect to the 3-inch rifle. This last will doubtless be considered heresy by the advanced artillerists; I refer them to the reports upon the first battle of Bull Run and the comparison drawn between the destructive effect upon bodies of men of the firing of the Napoleon rifles and of the naval howitzers. The ammunition supply and its service, both for infantry and artillery, demand especial attention, organization and drill, especially on the fighting lines, when in action, and should be in charge of officers selected for their capacity for this essential duty. The same may be said for the hospital service, and particularly for the stretchermen and their movements along the fighting lines.

Finally, I beg leave to add a single word upon the subject of the exercise and drill of the Naval Brigade. Upon this point I am in perfect accord with the very able prize essayist; I think that every word he says on the subject should be absorbed and digested. He has struck the right chord when he votes to abolish the "pomp and circumstance" of war, the charming dress-parade and review for the edification of the admiring crowd. The precision of the manual, the correct alignment of the columns, the cadence or length of the step, are matters of absolute insignificance to the rank and file of the Naval Brigade, as compared to their accurate marksmanship, to their knowledge of the piece, including its mechanism and care, and above all, to their individuality as fighting men. We do not require exercise in the elaborate tactical movements of battalion drill; on the contrary, confine this part of the drill to the simplest movements in line, in column, and by the flank. The drill we need is a practical exercise in the field of the movement of such a force when actually in presence of the enemy, and this is best found in the skirmish line and its development to the front by successive reinforcement from the main body and reserve into the fighting and supporting lines of battle. This drill should be altogether by bugle and signal, never by oral command. Add to this drill one for landing on

[illegible] Naval [illegible]

[illegible] These

[illegible] that they [illegible] every one [illegible] going [illegible] Depart- [illegible] every ship [illegible] at the present time the [illegible] officer in [illegible] the Adams [illegible] stay there, or any- [illegible] a private letter from [illegible]
curre[illegible] Board of Inspection a [illegible] officers. [illegible] called upon to make

and officer the organizations on board ships—in other words, lieutenant-commanders and lieutenants—that it would be practicable to get some sort of uniformity in regard to drill. Now the Board of Inspection require, as I understand, certain things to be done when they go to inspect—where they get the authority from I do not know, but they adhere pretty closely to the two manuals that Mr. Stockton referred to, with occasional deviations, agreeing very largely with what the senior officer thinks ought to be done. Therefore it seems to me of the first necessity that these matters should be straightened out, and it would very materially aid in the reorganization of the Department, or at least diminish in some measure the evils under which we are now laboring, till we can get some different way of managing things. I do not suppose there is an officer in the Navy, from the highest to the lowest, that would not gladly hail anything of that kind; I mean of course on our own side of the establishment. But there are some things that, in reading this essay very hastily, strike me as very good; here is one, "the absolute niceties of the service should be abolished in the drill of the battalion." It is a mystery to me why so much attention should be given to the seams of the trousers and all that sort of thing. There is another point that Mr. Hutchins refers to two or three times, and that is regarding the necessity of drilling the marines as boatmen. It seems to me absolutely necessary not only that the marines should pull their boats, but that every man on board the ship should know how to shoot a rifle and hit a target and also to pull an oar.

Lieutenant Staunton:—That is called for by existing regulations—not the oar part, but the other part—the small-arm drill and target practice.

The Chairman:—It has been now some three and a half years since I have been at sea and the material we had to deal with was pretty hard material to get any results from.

Lieutenant Staunton:—I believe you can teach any man to shoot fairly well if he can see. A man may be careless, or he may be nervous because he does not shoot enough to get over his nervousness; but he can be taught to shoot fairly well if sufficient time and attention are given to the subject.

The Chairman:—It seems to me that we have got to have a revolution in regard to the duties of the people on board ship. Servants are there now primarily to attend to the wants of the officers. Now, my theory is that that should be a secondary consideration, and the wants of the ship of primary importance. In the first place, there are entirely too many of them. The commanding officer has a staff of three. Why in the world one man wants three others to wait on him is a mystery to me; in the ward room, also, it seems to me there are altogether too many; it certainly takes four times as many as there would be on shore to do the same amount of work.

Ensign Rodgers:—Well, the work is different to a certain extent; you can't organize the work as you can on shore; it has all got to be done at once in a limited time.

The Chairman:—There is a certain amount of force in that objection.

Ensign Rodgers:—You don't get the same class of servants on board ship; it takes two or three times as many to do the work that a good servant would

do on shore—the more you make sailors out of them the less use they are as servants. I would rather have one man in the ward room as a first class servant than two that could go aloft, perhaps, and furl a sail in a pinch, and pull an oar, and hit a target once in a while, but are of no use as servants.

The Chairman:—That is quite right, it was the very point I was coming to. By reducing the number of servants and using them for nothing else, it would require a very small number to do the work; it would not be necessary to have so many.

Ensign Rodgers:—The ships would not require so many if they were not called away so much. They are liable to be called away in the middle of their work for ship's routine, drills, etc. The cook is likely to be called on deck and leave his galley half a dozen times a day to send down royal yards, when he may not be of the slightest use and when the whole dinner may be depending upon him. I thing it is better to reduce the number of servants and have them for that service and no other.

The Chairman:—I don't see why one steward and two cooks could not run the galley for all the officers. But they should have nothing else to do. That should be their business, and then the number of servants who attend to the rooms could be very much less than it is now. If I am not mistaken, that is what they do in the English Navy; they have mess men and a cook, and their servants are generally marines who come in and clean up the rooms.

Ensign Rodgers:—I do not believe in that. I think it is bad for the men to occupy these positions. The essay speaks of the desirability of having a change in the drill. Unless I have been misinformed, when we sent the expeditionary force down to Panama, two years ago, the drill all went to pieces and the officers got up a little drill of their own on the mail steamers going down. It did very well while down there. I think this itself is a criticism on the whole business, that we have a drill which is more or less legalized, yet call half a hundred men together and they get up a little arrangement of their own altogether different.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

# INFANTRY-FIRE TACTICS, FIRE DISCIPLINE, AND MUSKETRY INSTRUCTION, AND PRACTICE WITH RAPID-FIRING CANNON.

By LIEUTENANT-COMMANDER C. T. HUTCHINS, U. S. Navy.

Having had the honor to gain the gold medal of the Naval Institute for an essay on the Naval Brigade, and having, for want of opportunity, touched but lightly in that essay on the subject of infantry-fire tactics and musketry instruction, I desire to bring that important subject forward as it is now presented to us with improved arms, and at the same time I wish to include in the discussion the practice with rapid-firing cannon.

It is to be lamented that we are absolutely without any small-arm fire discipline and fire tactics in the Navy. That our system of musketry instruction should depend on the fancy of the commanding officer of any of our vessels of war, with the recommendation to use the incomplete Army system, and that the prize to look forward to is to redound to one's credit,—these, it seems to me, are sufficient to enable one to predict what the useful effect is of the musketry instruction as now taught in the service. Though our musketry instructions are faulty in the extreme, directions in our service for the exercise of riflemen and men at the rapid-firing cannon are numerous. Yet it is a matter of fact there is no systematic plan, except in a few instances, of teaching the men fire discipline under the most favorable circumstances. Our musketry instructions should be such as to effectuate the requirements of our (modern?) tactics.

The Army instructions in rifle-firing are wanting in the most important of all firings, volley or mass firing. Individual firing being the object sought after, the Army instructions are elementary.

The individual instruction being completed, the men are not taught the value and use of volley, group, and mass firing under the control

of leaders; and yet, in the elementary drills, the musketry instruction is all that can be desired for the seaman recruit.

To quote from the Army instructions of 1885, "If the *allowance of ammunition will permit*, the company commander should, if practicable, near the close of the target season, afford his command practice in *volley firing*. The object of this practice is not only to give the soldier instruction in a *class of fire that will, under some circumstances, be employed in action*, but also to make the company and subordinate officers familiar with the manner of controlling the fire of their command: to accustom the men when in ranks to the habit of relying upon the judgment of their officers as to the range and approximate adjustment of their sights, the extent of their fire, and the most suitable time for its delivery." For some unaccountable reason the Army still clings to the single loader, and volley and mass firing are not of so much importance with such an arm as with the magazine rifle supplied to our seamen, and in use by all first-class powers, with one exception, and now about to be adopted by that power. The days of the single loader are numbered, and it appears probable that our army will be the last to abandon it—perhaps not until the disappearance of the North American Indian. Its present retention by the Marine Corps is much to be regretted.

Individual fire was given up long ago in continental Europe, and I believe is now condemned in England. Neither afloat nor ashore must we hold to the idea that the average excellence of fire of the individual sailor is the test of his efficiency in battle, or that it is the established rule by which we may judge of the effective fire of the mass; therefore uncontrolled individual fire should not be used. It is only a few years ago that an English authority on the subject of infantry-fire tactics stated that independent fire of individuals was the curse of the English army; and this, I believe, was shown by the fire of the English troops in Egypt and the Soudan. Most certainly their firing has been unmercifully condemned by Major-General H. Brockenbury, C. B., who commanded in the Soudan campaign, "to the fame of the force he commanded."—To quote from his remarks on infantry-fire tactics, "I regret to have to say, and that is, they (British soldiers) cannot shoot. . . . Of course, we all know the enormous mass of lead that is fired away for every man that is killed or wounded, and what does that mean? It means that our soldiers are not trained to shoot as they should be." As our army stem of musketry instruction follows very closely that of Great

Britain, and might be said to be about the same, and as the musketry instruction of our navy is based upon that of our army, it would be well to heed these warning words, and not follow blindly a system of musketry instruction that is condemned in every country in Europe. For the Navy we must adopt a system of small-arm fire tactics that is in keeping with the advanced ideas of the day—a system that will qualify our seamen so that they may be able to fire in masses or by volley—*concentration of fire*, and the controlling of it as long as possible. After men have been taught to point their weapons, their instruction should take that direction which will fit them to be controlled at all times in their firings by a petty or commissioned officer. A French writer, M. E. Simonde, in "De la Tactique des Feux et des Armes à Répétition," 1884, says: "Let us use fewer cartridges in training men to attain an accuracy of *individual* fire, which has not in war the great importance usually attached to it, and let us make use of them rather in teaching the leaders the employment of fire"—to habituate them simply to adjust their sights and to aim correctly and quickly after having loaded; devoting more attention to fire discipline, rather than to providing for a wasteful expenditure of ammunition caused by hurried independent shooting. I am not only speaking of the instruction of men for the Naval Brigade, but also for those on shipboard during battle, where mass firing or firing in groups will be more effective than individual fire, which is a waste of ammunition, waste of time and waste of energy. In close action individual fire will be forced upon us; there is no human power at this time that can control men in their firing and in the expenditure of ammunition; in the field, authorities give 400 yards as the limit, and the more raw the men the greater this distance becomes. And here again we must not only have the magazine gun, but fire-arms that will need no change of sight after getting within this distance (400 yards) of an enemy; fumbling with sights under fire, at close quarters, should not be permitted.

In a most remarkable and most valuable English work on the subject of infantry-fire tactics by Captain C. B. Mayne, R. E., we find: "The independent fire of individuals in the field is of little, and we may say of no value beyond 400 yards; the only really effective fire is that which proceeds simultaneously from a great many fires directed on the same point—that is, from *concentrated fire*. Mutual co-operation is the secret of success in war. Individual action is a waste of power, tends to panics, and is in every way to be avoided.

The fact of the matter is that only very few men are individually good shots, especially when under fire, and those that are such have their skill nullified in the field by the excitement of the fight and by not knowing the range exactly, the almost all-important point for accurate shooting."

Taking all these facts into consideration, it does not appear that we should be carried away with the idea that a dispersed order of fighting will win battles in the future. Clouds of skirmishers moving to the attack open the fight, but they have no cohesion in themselves, and there will be a time during every battle when large bodies of men under good fire discipline and the control of leaders, must be brought forward in order to gain the fight.

In the concentration of the small arm fire on shipboard, let us take for example a group of men in the maintop of a ship; the order would be given for all the riflemen in the maintop to concentrate on a certain gun's crew of the enemy or any designated part of the ship, such as the conning tower, should it be like the Chicago's. To kill two or three men at five or six of the enemy's guns does him but little injury; but if you can disable or kill ten or eighteen men at any one gun, that gun is for the time disabled, not to speak of the moral effect produced; and with the secondary batteries of ships manned by small crews, a concentrated fire might possibly in a few seconds disable any gun by the killing off of the crew. We are all familiar with the fight between the warships Covadonga and Independencia, during the war between Chili and Peru, when the well directed musketry fire of the weaker ship played such an important part in her escape. To make a success of the concentration of fire and its direction under leaders, the groups or squads must be under the control of a petty officer, who should be under the direction of an officer of the ship. These squads or groups would be composed of not less than four nor more than sixteen men, and in the exercises the petty officer would be accustomed to handle these men, as well as take part in their instruction in firing and assembling at any part of the ship. In the instruction, the squads should be independent in their movements, and men should be detailed with each to provide ammunition—the supply coming from some designated place in the ship, always known to the leader of the squad. In the assembling of riflemen on deck from below, it is questionable if the custom of the service—having them form on the side opposite to the one engaged, in those ships that have bulwarks—is right, since they can be seen

and fired upon from the tops of an enemy's ship. In dealing with the sailor in our small-arm fire tactics, we must confine ourselves in our instructions, by devoting much time to the really essential things, and omitting those things that are of no practical use to the seamen in battle.

As the useful effect of fire does not depend on its rapidity, we may say that five rounds per minute is about the rate of firing with well drilled men; if in excess of this, the firing would become less accurate. At the present time we must deplore the want of effort in the right direction, and regret that the brain power should be devoted to obtaining a powder with greater initial velocity, instead of a powder that will vaporize immediately after firing, leaving no smoke, and permitting a firer to see an enemy at all times in battle. Such a powder has been in use several years in fowling pieces, and eventually must be adopted for use in our rifles. Those who have had any experience with revolving cannon know that it requires but 15 or 20 rounds to be fired in rapid succession when the gun is enveloped in smoke to such an extent as to hide the target from the gun-captain's view.* In all target practice it is very important that each shot be plotted, and that each man shall know where his shots struck the target. The plotting of each shot, with an explanation of the score, and the posting up of each firer's target, present it to the mind, and such an illustration is worth a cart-load of written reports and discussions on the subject.

For the purpose of plotting each firer's score, targets, Plate I, now in use at the Naval Academy, are found to answer all the purposes sought. Figure targets should not be used for teaching marksmanship, but for field practice they are indispensable. The explanations on these targets should, when necessary, call the firer's attention to the cause of bad shooting. It may entail more work on the officers of a ship; but the older officers should be given more time for the instruction of their divisions in the much needed fire discipline, the junior officers looking out for the day deck watches. We still find in the British Naval Gunnery Manual such words as these, that "the real exercises to cultivate the necessary dash and agility will be found in sail and spar drill." It is very doubtful if the ships of the future will be equipped with spars and sails to make sail drills of much benefit to the seaman; therefore, the time heretofore devoted to

* Smokeless powder, composed of prussiate of potash, chloride of potash, and sugar.

# PLATE I.

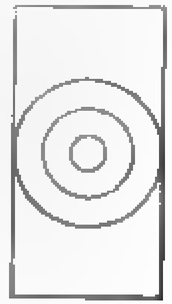
## RECORD OF PROGRESSIVE SMALL ARM TARGET PRACTICE.

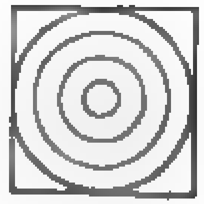
U. S. NAVAL ACADEMY, 188

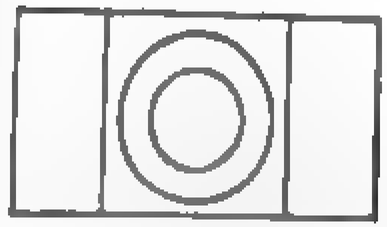
NAVAL CADET, , CLASS.

| DATE. | ARM. | DISTANCE. | ROUNDS. 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | TOTALS. | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

TARGETS.


3d Class.


2d Class.


1st Class.

these exercises should be taken up in rifle and rapid-firing gun exercises, with the expenditure of more ammunition. It is surprising to know that our service is about the only one in which prizes are not awarded for good shooting. Sometimes the officers of ships subscribe sums of money and offer prizes, worthy countrymen joining in the subscription; but that we should have to do this to encourage good marksmanship is a sad comment upon those that direct our drills. Our seamen should be encouraged in their target practice by offering them rewards and prizes, and by creating among them competition trials with battle conditions. Our present system of carrying on firing drills has been in operation long enough to convince the most sanguine that it is fatally defective; and it may be traced to the fact that there is no one under the government of the Navy that is directly responsible for any firing exercise under battle conditions—the real object of all our work; and until we have a Board of Inspection with unlimited powers, just so long will we be wanting. The work of overhauling target reports, and furnishing to the Navy a system of drills and exercises, ought not to be imposed on any bureau. All reports of exercises, particularly firing drills, should go to a Board of Inspection, to be by them examined, and this Board should be held responsible that our ships are in a high state of efficient fire discipline. Their responsibility would be sufficiently great in itself to preclude the possibility of any want of proper attention to the development of the higher requirements of fire tactics and its practical necessities.

There must be no doubt of what the duties of such a board should be; drill inspectors would confine their duties to the inspection of artillery fire both great and small, and everything that pertains to the fire of weapons offensive and defensive which fit a ship for battle, and her crew for a hasty disembarkation for operations on shore. To carry out such a system of inspection, our ships must go to sea and be required, under the eyes of inspectors, to go through their firing exercises, to land the battalion or Naval Brigade, and to practice volley and mass firing as we would expect to be called upon to do in battle. The bitterest opposition should be shown to all drills at these times that are not complete by the use of powder under battle conditions.

Rapid-firing cannon demand much drill practice; and frequent firing under the actual conditions of fighting the guns in service is of the greatest importance. The Hotchkiss Gun Company have made a move in the right direction in devising an outfit of drill cartridges.

The drill cartridge gives the needed exercise which is required in full instruction to perfect the gun's crews in the firings and the handling of the guns, without the cost entailed by the expenditure of full service charges.

Plate II. gives a drawing of the drill cartridge. The drill cartridge is in shape and weight the exact counterpart of the service cartridge. The case of this cartridge is a rifle barrel chambered and grooved to correspond with the service magazine rifle. A steel base and extraction head is fitted to the bottom of the barrel; the body of the cartridge is made of hard rubber and the head of brass, thus properly distributing the weights as they exist in the service cartridge. In the base a small spring is inserted to hold the small-arm cartridge in place when loaded, as otherwise in handling it might fall out. In this manner, when loading the gun exactly as in service, a small-arm barrel discharging its regulation cartridge falls naturally in the axis of the bore of the gun.

A box containing twenty of these cartridges is provided for each calibre of Hotchkiss gun on a ship. In the box is also placed a drill sight properly ranged for the small-arm ammunition. In drilling a gun's crew it is simply necessary to put the drill-cartridge sight in place on the gun and load the drill cartridges, an operation requiring about half a minute. The cartridges may then be distributed in the service ammunition boxes, and everything is ready for carrying out every detail of fighting exercise *without a single deviation from actual fighting service.*

It will be seen that it is the tendency of European nations to obtain if possible all the conditions of battle practice in the exercise of men with small arms and rapid-firing cannon; and if it is so important with large navies, how much more should it be so with our own small force, and with very few, if any, men to draw from in war times. Drills, exercises, and training must be completed before a war is inaugurated, for it is then too late to discipline and perfect men in their drills, which is all the more vitally important with the rapid-firing cannon.

The facility with which riflemen can protect themselves on shipboard from the fire of an enemy, the greater accuracy of their fire, the absence of smoke (smokeless powder being used) and consequent full command of the ship and uninterrupted view of the enemy, put small-arm fire on an equality with that of the machine and rapid-firing guns, and more particularly so, as the value of machine-gun fire is yet to be proved. Often a machine gun will

demoralize and drive away the crew of a large gun by a hail of bullets falling close around, striking carriage and gun, though few or even none of the crew are actually hit; this the writer is convinced occurred in the batteries on shore at Alexandria, Egypt, in 1882.

If skill in judging distances on shore is all-important, it is still more so on shipboard, where the objects aimed at advance and recede at great speed, as is the case with torpedo boats; therefore, men should be taught this exercise, or their fire will not be effective.

In laying out a scheme for small-arm target practice and instruction for the Navy, not only should the object be to develop fire discipline, with a knowledge of the arm and accuracy in its use with reference to our special needs, but we should also develop a true knowledge of the efficacy of fire when under the control of intelligent leaders—a fact not to be lost sight of when dealing with seamen, because of their lack of opportunity to attain the perfection of regular troops. Battle conditions should be assumed, and at no time should any firing take place unless some of these conditions are presented. Firing at targets hanging from a yard-arm is no instruction to the recruit. In the practice from the tops of a ship and from the boats, floating targets anchored at known distances should be used, and the same kind of targets when firing from the decks. A small boat protected by boiler plates and towed by a long line at good speed across a certain arc of fire, will give a practice that would be very useful against torpedo boats, though this practice could be obtained at any range on shore. It is the exception in our service to see any practice in firing from the tops—a class of fire from which we should expect good results, so long as ships carry fighting masts with protected tops. I am aware that there is danger in some ships of shooting away something aloft; but we might also say there is also danger of shooting oneself. In the practice with small arms the eye becomes accustomed to the use of sights, and any thorough system of musketry instruction would give to the seaman that accuracy in the laying of heavy guns so much sought after, and without which no ship is ready to give battle. General H. A. Morrow, U. S. A., on the subject of *rifle instruction and practice*, says: "It has done more to elevate the moral standard of the army than any other one thing. Temperance, abstemiousness, patience, perseverance and industry are cardinal social virtues, and it so happens that they are absolutely necessary qualifications of the marksman." It is well worth while to weigh these words carefully, that we may give more attention to rifle instruction and practice.

The frequency of accidents in the service on board ship after small-arm target practice might be reduced to a minimum if the drill instructors were compelled to report in writing after each firing exercise that all arms had been inspected and that all ammunition issued had been turned in and stowed where it could not be gotten hold of without orders. Again dummy cartridges should be nickel plated, so that they can always be known by the most ignorant.

To attain any degree of skill in firing, constant practice is necessary; and to avoid too great expense, reduced charges should be used. In order to carry out this plan on shipboard aiming tubes should be used, and a plentiful supply of ammunition and targets furnished to each ship. These tubes should be so mounted in the rifle barrel that all the conditions of firing would be the same as with the service cartridge, with the exception of the recoil, which could not be obtained.

The violence of recoil is a very important consideration with our present weapons, when a rapid fire is continued for any length of time, and it is very doubtful if a continued rapid fire of any accuracy could be kept up for a longer period than two and a half minutes, and then only with thoroughly drilled and experienced men. It may not be generally known that a great deal of bad shooting is due to the flinching of the firer caused by the heavy recoil, and the uncomfortable grip of the rifle, which militates against its being held firmly against the shoulder. With the revolving cannon, the less the force of recoil the greater the ease with which the handle of the gun can be revolved.

Assuming the energy of recoil of the Lee magazine gun to be fifteen pounds, and that fifty shots can be fired in the two and a half minutes, the fatigue to the shoulder and the muscles of the arm with the present weapons caused by such a fire would be exceedingly great, and we may very well doubt if any useful effect would be produced with the last ten or fifteen rounds fired.

With these facts before us, how necessary it is that we should very frequently have the actual conditions of battle practice, that we may be able, when called upon, to keep up an effectively aimed and rapid fire. Persistent effort is necessary in order to build up a body of [illegible] well skilled in the handling of small arms and rapid-firing [illegible] under battle conditions. Possibly a gunnery school [illegible] board at some convenient location on the Atlantic [illegible] the necessary want in this direction, when [illegible]

practice and drills would be attained, and one system, with no deviation therefrom permitted, strictly enforced on every ship in the service. In the establishment of a school of this character, it would be well to bear in mind that it is not necessary to demand too much from the seaman, such as filling his head with fine theories which he does not understand, and much less, never able to put into practice. Practical training must be the object sought when dealing with the seaman, in proof of which you have but to look at the navies of Europe to-day.

Here I would call attention to the following report, in awarding the Bailey Medal to one of the apprentices of the Training Squadron:

The Bailey Medal is awarded to —— ———, seaman apprentice, 2d class, serving on board the U. S. S. ———, 1887.

The following is a summary of the result of the examination of the contestant selected as best qualified on the ships of the Training Squadron, viz:

| | Knotting and splicing. | Sail-making. | Heaving lead. | Heaving log. | Signals. | Exercise as captain of [redacted] | School of soldier. | Small-arm target firing. | Sword exercise. | Swimming. | Sewing. | Knowledge of his accounts with paymaster | Condition of clothing. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maximum of marks in several subjects. .... | 50 | 50 | 50 | 25 | 50 | 75 | 75 | 50 | 25 | 25 | 25 | 25 | 25 | 550 |
| —— ———, seaman apprentice, 2d class, U. S. S. ———........ | 38 | 24 | 47 | 20 | 45 | 70 | 60 | 17 | 21 | 24 | 20 | 13 | 22 | 421 |

Having adopted the magazine rifle for the seaman, we must give more care to our fire discipline and the expenditure of ammunition, particularly with landing parties. In order that the fire of the men may be controlled, magazines should not be used unless specially ordered. The detachable magazine of the Lee gun answers this purpose admirably; and in the instruction of the men, the piece would always need to be thrown to a perpendicular position opposite the left shoulder in order to attach the magazine. Officers' attention is thus attracted to the men in battle when loading, and the magazine fire kept in reserve for certain emergencies, and for the moral support which it would give to men who are aware that they have a reserve of fire constantly on hand, and a power to inflict sudden loss on an enemy at any critical moment of a fight *which no single loader can give.*

German and French authorities claim that the result of peace times with fairly drilled men must be ten times greater than those obtained in war; and assuming that the percentage of the wounded to the killed will be 7 to 1, it would be interesting to know what our men would do at the present time with small arms both afloat and ashore.

Captain Mayne, R. E., publishes some startling figures obtained from Prussian experiments, the same results having been obtained in Austria; that up to 770 yards the Prussian company column (250 men), lying down, will suffer, on an average at all ranges, two or three times as much as a company in line lying down; and that *the company column standing up* suffers but *little more loss than the company in line*, but beyond that distance its losses are more than double that of the line; that is, 770 yards in line 18 to 35 per cent, in company column 30 to 45 per cent, at 550 yards in line 30 to 60 per cent, in company column 40 to 65 per cent. It might be well to question these figures; but with a nation so practical as Germany in the instruction of her soldiers, it is doubtful if mistake in such experiments could occur.

The Italians say that the column suffers two or even three times as much as the line formation. At short ranges the difference is less, but at less than 550 yards the loss of men in column will be 50 per cent greater than that of men in line.* To continue this subject might divert us from the main issues of this paper; but it would be well to bear in mind in our musketry instruction and practice, that the results and figures obtained at these distances must be impressed on the minds of the men. They should also be impressed with the fact that, kneeling at 600 yards or more from an enemy, the losses inflicted would be less by one-half what they would be if standing, and if lying down the losses would be about one-fourth. Here the "Firing lying down position—Texas Grip," with the feet toward the enemy, as given in Captain Blunt's Rifle and Carbine Firing Instructions, appears to be best adapted for the protection of men from the enemy's shot. It also relieves the men's shoulders from the recoil of the piece, though not so easily taken as the prone position, which might be a consideration worthy of notice in the rapid advance of skirmishers. But no commander should be guilty of the mistake of allowing his men to lie down at short range, when advancing with an attacking force, more particularly if the force has met with much loss.

* This we very much doubt, for gaps must be filled in the line.

The Lee magazine gun, with the present detachable magazine, is not adapted for the use of blank cartridges, a defect that should be remedied; and in blank-cartridge practice with the rapid-firing guns, the experience on board H. B. M.'s ships Curlew and Black Prince, of the Channel Squadron, in the late naval manœuvres, August, 1887, in converting loaded into blank cartridges, ought to be remembered and avoided.

England proposes the adoption of an arm of calibre .307, and this fact, together with the reported experiments carried on lately in Germany and France with small calibre rifles, calibre .296 in the former country and .315 in the latter, if true, will cause a marked change in the small-arm armament of different countries. Greater range without raising back sight, thus doing away with the changing of sights at short ranges; weapons sighted with a full foresight; flat trajectories, which give a larger fire-swept zone; more rounds of ammunition, both as to weight and the number that can be carried in the magazine; slight recoil, and smokeless powder, will be the leading features of these new weapons. It is barely possible that a lighter rifle may be produced, as the question of rough usage in service will have to be considered. But we cannot help thinking that a test of the smaller calibres in battle will be the only means of ascertaining their superiority over the present arms, so far as the power to destroy life as well as to disable is concerned, which is the object of small-arm fire. It is claimed for the smaller calibres that they maim instead of kill, and that a wounded man requires others of the fighting force to care for him, while the killed need no care. In a great war that would demand all able-bodied men, women would have to care for the wounded, and the fighting force would not be decreased to any appreciable extent—in fact, in a navy, it would be a matter of no moment. A reduction in the calibres of small arms cannot follow the rapid advance made in that direction by heavy guns, the targets for the latter changing every day and at any moment of a fight, while those of the former always remain the same.

*General Plan.—All* men on shipboard, without exception, to be instructed in small-arm firings,—the word non-combatant should be stricken from our naval dictionary. At no time should a boat's crew be excused, be it barge or gig, nor should any one be excused connected with the engine-room force. Important or necessary work in the fire room or engine room can be carried on under an officer,

when the rest of the crew under an officer are cleaning ship in the morning or forenoon watches. If there is anything on shipboard that will cause discontent it is the excusing of a class of men or a boat's crew from drill; and what can be more annoying to an intelligent and zealous drill officer than to be called upon to excuse men while his drill is in progress? Every man in the Navigator's division stationed on deck should be instructed in the rapid-firing cannon, also the men belonging to the spar-deck guns, and the marine guard.

The officer in charge of each division should send to the commanding officer, through the executive officer, a written report of all men in his division excused from drill each day and for what purpose excused, the report to be forwarded to an inspection board. An equal division of the labor on shipboard for both officers and men, no matter how obtained, is the only road to efficiency and to a contented and well-drilled ship.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

# THE V GUN SHIELD FOR CRUISERS.

By Chief Engineer N. B. Clark, U. S. N.

All the new cruising vessels yet designed by the Navy Department are to have the ammunition raised from the magazines to the deck by the old fashioned shell whip hoists, and then transported along the open deck to the various guns, the crews of which are almost entirely unprotected; and this in the day when a storm of small missiles from machine gun, Hotchkiss, and rapid-fire shell guns makes life on the open deck utterly impossible, and when exposure, in combat with a protected adversary, is equivalent to death, and with it defeat and humiliation. The new offensive weapons by which the decks of warships can now be swept by storms of small percussion shell, which readily penetrate the sides of unarmored ships, imperatively demand and necessitate a change in the plan of mounting guns, and of the manner of conveying ammunition to them. It makes but little difference what the number and power of guns a ship may carry, if the crew cannot work them, or get ammunition to them, they will avail but little in a combat with a protected adversary, and protected the adversary can be, if he chooses, without increase of displacement, or abatement of speed or sea endurance.

The contest of the two British ships Shah and Amethyst, manned by highly disciplined crews, with the Peruvian monitor ram Huascar, "manned by a heterogeneous crew of undisciplined insurgents," would seem to prove that one ton of armored displacement was more than a match for eight tons of unarmored. It would therefore be better to have fewer guns well protected than a greater number unprotected.

The annexed illustrations are intended to show that the gunners of cruisers can be completely protected by appropriate armor while working the guns, and that the ammunition can be conveyed directly

to the breech of each gun through a vertical tube, or hollow shaft, by which the gun is trained, by means of a pneumatic engine situated in a passage leading to the magazine, below the water line, into which the vertical tube extends.

Fig. 1 represents a plan view of a section of the gun deck of a cruising vessel. The drawings are made to scale, and the guns represent the standard 6-inch rifle. The side of the ship has four feet tumble home, the guns and shields being mounted in little bay window-like projections, as shown in Figs. 1 and 2. The gun has no horizontal motion independent of the shield, and when the gun is trained to fire shot, the shield is also trained to deflect them coming from that direction. Attention is called to the very sharp deflecting angles at which the shield would receive shot coming from the direction in which the gun is trained, and also to the great range of fire which can be given broadside guns mounted in this manner.

Fig. 2 represents a cross section of a cruising vessel on the line *ij* of the plane view, Fig. 1. *A* is the curved shield for water line defense. Beneath this curved shield is a passage leading from the magazine, and extending along the ship's side under the broadside guns. *S* is a vertical tube, or hollow shaft, by which the gun and shield on the deck above are trained horizontally, and through which the ammunition is elevated into the shield near the breech of the gun. When the ammunition reaches the top of the vertical tube *S*, an appropriate guide causes it to fall over into the little truck *H*, which is held in position by a spring; one of the loaders, standing at the breech of the gun, then draws the truck out by means of a lanyard, and takes the ammunition from it, the truck being drawn back by the spring into position for another load.

Immediately over the gun, the upper portion of the broadside V shield is partitioned off by a cushioned platform *I*, on which the captain of the gun reclines in a prone position, aiming the gun through the sight hole *Z* in the apex of the V shield. This position over the gun would not be uncomfortable, as the concussion and vibrations of air producing sound are generated from the muzzle of the gun, from which the man would be well protected. This position, which is eminently adapted to the V shield, presents a less cross section of human anatomy than any other.

The shaft of the pneumatic engine *M* has cut upon it which engages in the gear wheel *N* secured to the lo e vertical hollow shaft, or tube *S*, and a lever controlling t

of the pneumatic engine is arranged convenient to the hand of the captain of the gun, so that he can train it with great rapidity and accuracy on any object, and hold it firmly in any position.

The broadside V shields are pivoted in the deck above at *W*, and on the deck below at the top of the vertical hollow shaft and conduit tube *S*.

The shield and gun are rotated on the anti-friction rollers *T* and *Q*, which are protected between two deflective plates, the upper one, *R*, being attached to the vertical hollow shaft *S*, and forming a part of the bottom of the shield, the lower one being attached to the deck.

Fig. 3 represents the plan view of a 10-inch rifle mounted *en barbette* on a V shield as a pivot gun, with all round fire.

Fig. 4 is a plan view of a loading lever by which it is proposed to convey the heavy ammunition of large guns from the upper end of conduit tube *S* (Fig. 5) to the breech of the gun.

Fig. 5 is a cross section of the V shield, Fig. 3, on the line *k,l*.

Fig. 6 is a plane view of *X* in Fig. 5, a device actuated by a spring for closing the opening between the gun and the shield when the gun is elevated.

Fig. 7 is a cross section on the line *m,n* of the vertical hollow shaft, or conduit tube *S*, which is given a deflective form.

In Fig. 5 *C* represents the loading lever, Fig. 4, which has two arms of unequal length, and is pivoted at the fulcrum between them. *E* represents a small truck, which traverses the long arm of the lever and is secured to it.

When the ammunition is pushed up through the vertical tube *S*, a guide causes it to fall over on the truck *E*, upon which, by means of a lanyard, it is drawn out to the end of the long arm of the lever, where it is held by a spring catch. Hydraulic or pneumatic power is then applied to the small oscillating cylinder *G*, the piston rod of which is attached to the short arm of the lever, thereby raising the ammunition on the long arm to the breech of the gun, as shown by the dotted lines in Fig. 5.

The pivot gun V shield is also trained by the pneumatic engine *M*, the lever for controlling the valve gear of which is marked *B*.

By means of the mechanical appliances described, two men can operate a very heavy gun, while there is ample room in the V shield represented by Fig. 5 for at least four men.

It is hardly necessary to state that the mechanical appliances herein described are not in any manner dependent on the principle of

deflection, as they can all be applied to an ordinary gun platform, either with or without any form of armor.

The deflective V shield was first brought to the Ordnance Bureau early in 1881, but received no c whatever.

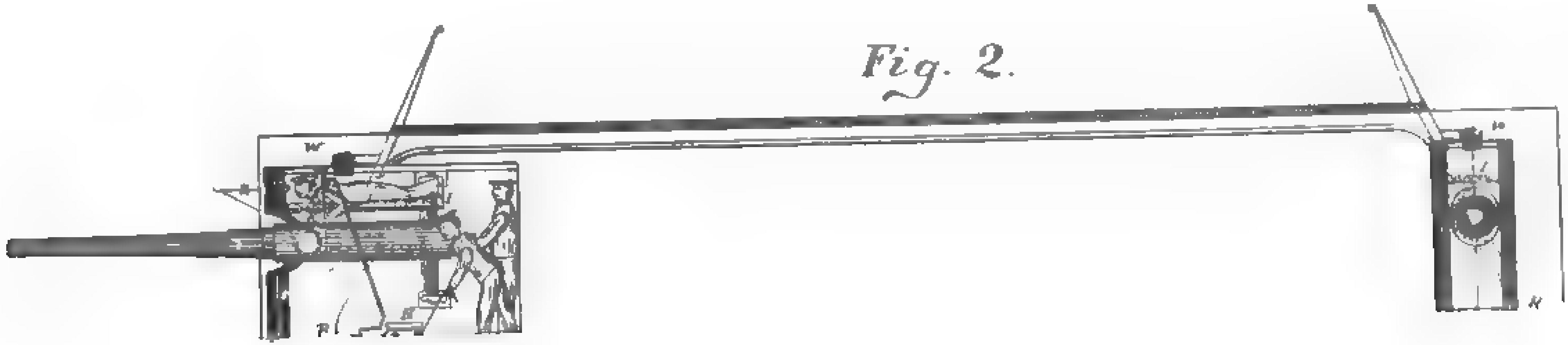
The Naval Appropriation Act of 1882 contained a the appointment of a Naval Advisory Board, to c d naval officers and two civilians; the Act declari " shall be a member of said board who has any n indirect, in any invention, device or process, patent or be used in the construction of the vessels."

The board was duly appointed, met, and gave each of t presenting plans a hearing, and then on January 31, 1883, i preliminary report to the Hon. Secretary of the Navy, in said: "The system of deflective decks submitted by P. A. N. B. Clark possesses great merits," and "the gun shiel by Mr. Clark possess decided merits." It is under od the opinion of all the seven members of the board.

After making the preliminary report the board met again and adopted the gun carriage designed by the Chief of Ordnance, instead of the armored gun carriage or V gun shields which they had formerly reported upon as possessing "decided merits."

The objection made to the V shields is their weight. While the weight of the steam machinery of the Chicago is 419 pounds, and that of the Boston and Atlanta 448 pounds per I. H. P., the weight of the machinery proposed by me, having separate passage and emergency powers, would not have exceeded 150 pounds, thereby gaining sufficient weight to increase the power and speed, with great economy of fuel at passage speed, and to mount all the guns in invulnerable V shields, completely protecting the men, and avoiding the transportation of ammunition along the open deck, thereby giving the ships about eight times the fighting force they now possess.

Fig. 2.



range of 1816 yards, while the second round gave a loss of 68 pounds and a resulting range of 2492 yards. Range tables for introducing both variables are to be provided the gunners on a brass plate attached to the pressure gauge.

Lieutenant Zalinski claims for this gun great rapidity of fire. He believes that with trained men the gun may be fired at the rate of once each minute. In the trial before a U. S. Naval Board, in June, 1886, with untrained men and without great effort being made, five rounds were fired in nine minutes and forty seconds. This was with the old form of projectile, involving the placement of the gas check, etc. The accuracy of fire in these five rounds was also remarkable. The range was 1613 yards, the elevation 10° 40′, the pressure 1000 pounds, and the "cut off" set to produce a loss of 50 pounds. Four of them attained exactly the same range, the other having gone only seven yards beyond. The maximum lateral dispersion was equivalent to only 6.2 yards. The wind was quite variable, but no attempt was made to follow it except once, just after the first round.

A 2-inch rifle gun has now been built which is to be tested, even to the final bursting of the gun, to establish the limits to which rifling can be safely used. A torpedo cruiser to carry two 10½-inch and one 12½-inch gun is now building for the U. S. Government. The range of these guns will be at least one mile. The 10½-inch shell will carry 200 pounds of explosive gelatine, equivalent, according to Zalinski, to 326 pounds of dry gun-cotton. The 12½-inch will carry 400 pounds of explosive gelatine, equivalent to 652 pounds of dry gun-cotton.

In comparing the pneumatic gun with gunpowder guns, Lieutenant Zalinski says: "The feasibility of using gunpowder for the propulsion of shell charged with high explosives is continually broached. It has been frequently tried, but invariably with final disastrous results, where the experiments have been carried up to moderately *large* charges.* By large charges, I refer to shell charges not less than fifty pounds and reaching up to one thousand pounds, and even to shell charged with a ton of high explosives.

"The advocates, or rather the predictors, of t e of sives from powder guns also demand *penetrati* b e ex If *large* charges are to be thrown, the shell m c ly thinner, and it is very doubtful if it will then wit nd t c blow it receives upon striking the target, as to e te thickness of armor. The battering shell of 100

* Proc. Nav. Inst. 13, 417; 1887.

contains a bursting charge of only twenty-five pounds of gunpowder. It would seem that the walls of the shell would have been made as thin as consistent with ability to perforate armor without breaking up.

"Assuming that twenty-five pounds of a high explosive could be substituted for the gunpowder, it is very doubtful if it could be carried through heavy armor successfully before explosion. There is no record of large battering shell fully charged with gunpowder having perforated armor over six inches in thickness, without explosion until perforation. On the contrary, explosion takes place prematurely, almost immediately upon impact, with the result of less injury to the target than that produced by an uncharged shell. Much more surely will this be the case if a high explosive be substituted for the gunpowder, as the bursting charge, unless the shell cavity is well cushioned. To do this involves reduction of explosive capacity. The energy available, after breaking up the very thick and tough walls of steel shell, will be but little greater than produced by the gunpowder. The effect as to the material injury or man-killing power will not much exceed that producible by the shell charged with gunpowder.

"In firing a shell from a powder gun, the walls of the shell must necessarily be sufficiently strong to withstand the initial shock. This limits somewhat the capacity for bursting charge, even when armor piercing is not sought for. If a high explosive is used, some cushioning device is requisite, and a further reduction of capacity ensues.

"Assuming that a shell charged with some of the high explosives can be thrown with safety from a powder gun under normal conditions of pressure, it is known that abnormal pressures, varying therefrom as much as 5000 to 12,000 pounds per square inch, are not infrequent. This may be looked for especially when the gun is warmed by continuous firing. In addition to this, the shell and the contained charge may become warmed by remaining in the hot gun bore some little time before being fired. The high explosives increase very rapidly in sensitiveness by slight increments of heat. If, then, with this condition of increased sensitiveness we have in addition an abnormal pressure, a premature explosion is very likely to occur. Much more will this be the case when the bursting charge is one of the high explosives. In this connection another matter is to be considered. It is well known that the high explosives are capable of producing more or less violent explosions, depending

upon the character of the initial shock or detonation. The more insensitive the explosive the more powerful must be the detonating charge to produce an explosion of the first order. Fulminate of mercury appears to be requisite in all cases. But fulminate of mercury is even more sensitive to shock than either ordinary dynamite or dry gun-cotton; hence the resulting shock must be tempered so as not to explode the more sensitive *detonating* charge rather than the specially insensitive *bursting* charge. Wet gun-cotton has been substituted for powder charges, but being quite wet reduces its explosive ability nearly to par with gunpowder. Particularly is this the case where no detonating charge is used of dry gun-cotton and fulminate of mercury. Where the explosion takes place by simple impact, not alone is it of a low order, but, as the initial point of explosion is from the front, the resulting injury to the target is less than from a blank shell." The author quotes Commander Folger, U. S. N., in support of these latter views.

In discussing the effect of tamping the author says: "A cartridge of 8 ounces of dynamite was suspended in superficial contact with an iron plate three-quarters of an inch thick and there exploded. The result was a simple indentation of the plate. A charge of 8 ounces was again suspended against the plate, but over it was loosely suspended a piece of angle iron open at both ends and of such size that the inscribed circle between its sides and the plate was less than the cross section of the charge, which was cylindrical. Thus there was no direct pressure against the cartridge, yet a large elliptical hole was blown through the plate considerably longer and broader than the cartridge. This experiment was repeated with almost identical results; when both plates were placed together a hole was blown through *both* plates."

Again: "Comparisons are frequently made as between the high-angle fire of the pneumatic gun and the flatter trajectory of high-power powder guns. The comparisons are persistently made, notwithstanding the fact that it should be considered more as a torpedo-projecting machine than as a gun, and that the comparison should be made with torpedoes rather than guns. Nevertheless, even when considered as a gun, its high-angle fire is not altogether a detriment, and possesses important elements of efficiency as such, even when compared with high-power guns.

The experiences at the bombardment of Alexandria, a 1
trials from English ships under the most favorable con o

that the great accuracy of fire of high power guns is in a measure neutralized by the unstable platform which the ship gives. From this it would appear that naval combats, instead of taking place at ranges of from 5 to 10 miles, will rarely begin at much more than one mile range, and the tendency will be to come to closer quarters. Two miles may be considered the longest ranges at which attack of fortifications will take place." Hence, both "will be at such ranges as to make it possible to bring into play the pneumatic gun."

"The high-power guns, with their relatively flat trajectories, will be thrown out as to range, more by slight changes of angle due to the unstable platform, than will the higher angle fire of the pneumatic gun. The change of range due to error of judgment as to proper instant of firing will be much greater with the high-power guns than with the pneumatic gun. The variations of the latter are more likely to come within the limits of error in judgment of distances.

Again, at the short range mentioned, the high-power guns have, owing to the flatness of their trajectory, only the vertical projection of the sides and turrets of the ship as the available target, and missing these, no result can follow. This portion of the target is most heavily armored. On the other hand, the torpedoes from the pneumatic gun have, primarily, the over-water hull of the vessel, involving both its deck, which is relatively large in area and weak in armoring, and the vertical target to which the high power guns are limited. To this last, if the calibre of the gun is moderately large, serious injury may be done, directly and indirectly, while the deck, if struck, is sure to be crushed in.

But, in addition to the over-water hull, it has the very great chance of doing fatal injury to the under-water hull, if missing the direct hit of the target.

No small element, in considering the effectiveness of this weapon, will doubtless be the moral effect. The knowledge that escape is not assured when the enemy's missile has failed to make a direct hit, and that the danger may even be *enhanced* by that miss, will not have a reassuring effect on the crew of the vessel attacked."

The writer then considers the use of this weapon for coast defense, countermining, for defense of ships and as an adjunct for ships in ramming, and for torpedo rams. The paper is illustrated with a number of cuts.

By direction of the Secretary of the Navy, a test of the pneumatic gun was made September 20, 1887, by anchoring the Silliman (a

condemned coast-survey schooner, 80 feet long by 20 feet beam) at a distance of 1980 yards from Fort Lafayette, and using her as a target. The projectiles contained 55 pounds of explosive gelatine each, and three of them were sufficient to completely wreck the vessel. A description of the trial may be found in the *Army and Navy Journal* or the *Register* for September 24, 1887. Instantaneous photographs of the appearance of the target after each shot occur in the *Scientific American*, October, 1887. Some delay having arisen during the experiments with the Silliman, additional experiments for rapidity in firing were, according to the *Army and Navy Journal*, October 8, 1887, made September 30. Ten shots were fired, each projectile being loaded with 55 pounds of sand, and weighing complete 140 pounds. Firing commenced at 10.42 A. M. and ended at 10.52.30, or about one shot a minute. In the next shot the projectile contained 100 pounds of sand, and it weighed filled 203 pounds. With an elevation of 32°42′ it had a range of over two miles and a half. Time of flight 24½ seconds. Initial pressure of compressed air 975 pounds, final 825 pounds. Two similar projectiles, with an elevation of 15°, were fired with the gun sighted for 15 yards to left of target. The shots fell within 3 yards to left. The first projectile was 10 seconds in flight; initial pressure 750 pounds, final 625 pounds. The second was 9.04 seconds; initial pressure 750 pounds, final 615 pounds. Range 1772 yards. Of the time shell fired, two fell short 50 to 70 yards. Six would have hit a target the size of the Silliman, and two would have exploded sufficiently near to have injured her seriously. This was the first time that rapid firing with a large number of shell had been attempted, and the result indicated that a modification in the connections between the storage reservoirs and the gun was needed.

The experiments with this gun have given rise to co le cussion. General Berdan gives his opinion of the e of t in the *Army and Navy Register*, October 8, 1887, replies in the *New York Commercial Advertiser*, ol 17, marized in the *Army and Navy Register*, October 22. *York Commercial Advertiser*, August 30, Zalinski also repl criticisms of General H. L. Abbot. In an interview in t *ington Post*, October 16, Lieutenant John P. Finley, of Service, criticises the gun in the light of the dyna ex made at Sandy Hook, and points out how moisture on in the atmosphere may prematurely fire the electri of the gun are strongly defended by Colonel John Hamilt

*Army and Naval Journal*, October 29. This is but a minute part of the literature to which this invention has given rise.

Lieutenant C. A. L. Totten, U. S. A., proposes, in the *Army and Navy Journal*, July 23, 1887, that "Dynamite Archery" be resorted to, ships being armed with catapults, and *dynamite grenadiers* with crossbows from which arrows tipped with dynamite may be thrown.

Experiments in firing shells loaded with dynamite, by Mr. B. D. Stevens' method, were tried October 11, 1887, at the State Arsenal, Montpelier, Vt. The piece was a twelve-pound brass Napoleon; the shells were spherical, and the charge one-half pound of 35 per cent dynamite, a time fuze being used. The shells were fired with the usual service charge of two and a half pounds of powder. Five rounds were fired without any premature explosion. (*Army and Navy Register*, October 15; *Army and Navy Journal*, October 22, 1887.)

From the *Daily News*, Newport, R. I., October 24, 26 and 28, 1887, we learn that experiments have been made at the torpedo station to test the process proposed by Mr. Serge D. Smolianinoff for firing nitroglycerine with safety from gunpowder guns. His secret consists in rendering nitroglycerine perfectly insensitive to concussion or to detonation by heat, or by any means except by his patented burster. He further claims to be able to explode his shell at any point of the trajectory or after penetration.

The experiments consisted, after some preliminary trials, in firing shells filled with the mixture from service guns with two-pound charges of powder. Three filled shells, unfuzed, were fired at a stone wall forty-seven paces distant, without premature explosion. The remainder, fuzed, were fired up the bay. There was no premature explosion in the bore, and the shells exploded in mid air at a distance of about a mile, after about five seconds.

Mr. Smolianinoff had previously fired over 300 shells from a condemned 20-pound rifled Parrott, using an 8-inch conical shell completely filled with the prepared nitroglycerine, and a 3 pound charge of Dupont's F. F. powder, without having had a failure. The account of some of these earlier experiments will be found in the *Daily Alta*, San Francisco, Cal., June 13, 1887.

The *Illustrated Naval and Military Magazine*, **5**, 402–412, December, 1886, contains a quite interesting paper on the use of "High

Explosives in Warfare": meaning thereby their use as charges for projectiles from guns. The paper opens with a lengthy description of the pneumatic gun.* This is followed by an account of the experiments made by the U. S. War Department † with explosive gelatine, and finally the experiments in Germany, Italy, Switzerland, and elsewhere with gun-cotton, hellhofite,‡ romite, Parone's explosive, and nitrocolle. The paper is liberally illustrated with cuts of apparatus and projectiles, and of fortifications and the like, showing the effect of the explosions.

It is stated that romite is a solid, containing neither nitroglycerine, gun-cotton, nor any analogous compound. It can only be exploded in a closed vessel by means of a dynamite cap, but this may occur at the lowest temperature. It can be manufactured without an extensive plant and at an extremely cheap rate. Romite was invented by Mr. Sjöberg, a Swedish engineer, and has been tested in shells by the Swedish artillery. The results were considered satisfactory, but only small amounts were used.

Parone's explosive consists of two parts of potassium chlorate and one of carbon disulphide. From experiments in Italy with the 9-cm. and 15-cm. projectiles it was concluded that this mixture was an exceedingly safe one; that it would not explode without a fuze—not always a desirable quality—and that although its effects were not strikingly superior to those of powder, they increased rapidly with an increase of calibre. On the strength of this report the explosive was fired from a 24-cm. mortar at a range of 3000 m. The mortar burst at the first discharge. The commission recommended the separation of the two constituents of the mixture, but this plan does not seem to have worked well.

Nitrocolle is, according to the *Belgique Militaire*, a new explosive discovered in Belgium, which is as powerful as nitroglycerine, but much easier and cheaper to manufacture. To make it, strong glue is placed in cold water until it has absorbed the maximum quantity of the latter; the mixture is next solidified by means of nitric acid, and afterwards treated with a mixture of nitric and sulphuric acids, as in the preparation of nitroglycerine. The resulting substance is finally washed several times to remove the excess of acid.

In summing up the results of the Italian experiments i
n shell, the *Rivista d'Artiglieria e Genio* c

Nav. Inst. 11, 287; 1885. † Loc. cit. 13, 411; 1887.
‡ Loc. cit. 11, 771; 1885, and 13, 240; 1887.

the Hellhoff's composition is a perfectly safe explosive, but that its power is by no means so great as had been expected.

In conclusion the writer says, although these experiments furnish few instances of full and complete success, we may infer that the future of high explosives is assured. It can now only be a question of time before the use of these agents in powder guns is rendered safe and effective.

An interesting series of experiments on Roburite* was carried out on June 14 at the School of Military Engineering, Chatham, under the superintendence of Major Sale, R. E. This explosive belongs to the Sprengel class, being a mixture of two substances, neither of which separately possesses explosive properties; in this case both components are solid, and the resulting mixture has a sandy, granular appearance, somewhat resembling the commonest yellow sugar. Roburite is the invention of Dr. Carl Roth, a German chemist, who claims for it the following advantages over other explosives:

1. That the two components are perfectly harmless and inert separately, so that they can be stored and transported without any restriction whatever.

2. That even when mixed or ground up together in ordinary coffee, cement, or flour mill, the mixture is perfectly safe to handle and use, as neither percussion, friction, nor the application of an ignited or heated body will cause it to explode; this can only be effected by using a detonator charged with fulminate of mercury.

3. That, when detonated, roburite produces neither spark nor flame, and will not therefore ignite either fire-damp or coal dust in mines. Dr. Roth states that this point was decided by the trials of the Imperial German Commission upon Accidents in Mines, and that in consequence this explosive is now being introduced into the coal mining regions of Germany, as affording absolute safety to the men employed.

4. The amount of noxious gases produced by its explosion is so infinitesimal that for this reason alone it is superior to other explosives in common use for deep mining work. The report from a mine in Westphalia, with shafts about 1500 feet deep, states with reference to roburite: "The men are not inconvenienced by the gases, and experience no difficulty whatever in breathing the moment after a shot has been fired, and they resume their labors at once."

* Proc. Nav. Inst. 13, 420; 1887.

5. Roburite is not subject to deterioration through climatic variations of temperature. It should be kept dry, but if it becomes damp, its strength can be safely restored by drying.

The object of the trials was to test roburite in comparison with gun-cotton, dynamite and blasting gelatin. The programme of the experiments actually carried out was as follows:

*A. Safety Tests.*—After being ground through a small hand mill, the substance was struck direct and glancing blows with heavy hammers upon iron plates, without any result. Flame was then applied to a portion of it by means of a short length of Bickford fuze, but without igniting the mass; thrusting a red hot iron from a portable forge into the roburite caused only slow combustion and crepitation locally, which ceased when the iron was withdrawn. When a quantity was put on the forge fire it merely burned away like an ordinary combustible. Dr. Roth wished to fire a powder charge in contact with the roburite, but it was considered that the above named tests were more severe.

*B.* Tests on mild steel plates 2 ft. 6 in. by 2 ft. 6 in. and of various thicknesses. These plates were laid flat in shallow trenches, a hollow being left underneath the central portion of each plate; heavy timber balks were stacked around each square trench, with the object of showing the comparative dispersive force of each explosive.

1. Three pounds each of dynamite and roburite were placed on the centre of plates 2 in. thick, some sandy loam being piled loosely on top. The results of detonation were that the dynamite produced a dent in centre of plate 1¾ in. deep; the indentation produced by the roburite was about 1½ in. deep, but the bulge appeared to have a wider area than in the former case.

2. Five pounds each of roburite and gun-cotton were th ex
upon the same plates, with the result that, in the for
plate was smashed into four tolerably equal pieces, wh t
cotton made a breach through the centre of t l
resembling that which would be caused by the on
projectile. The diameter of the hole was roughly 12
radial fissures almost reaching the edges, the k 15
plate being at the same time bent into the shape a
this would seem to have been a remarkably tough ece
The timber balks were scattered in all directions.

3. Eight pounds each of dynamite and roburite
nated upon plates 3 in. thick. The dynamite ca

2¼ in. in maximum depth, while the roburite gave a bulge 3 in. deep in the centre, and of a larger area, reaching apparently almost to the corners of the plate.

4. This series of tests was concluded by exploding 12 pounds each of roburite and gun-cotton on plates 4 in. thick, rather more loam being heaped on top of each. The roburite caused a wide indentation 1¾ in. deep in centre, while the tremendous local force of the gun-cotton was exemplified in a striking manner. In addition to an indentation 3½ in. in greatest depth, a small crack appeared to extend right through the plate, this crack corresponding with one edge of the lowest slab of gun-cotton, the rectangular shape of which could be clearly seen indented on the steel plate, the depth being ¼ in. at the crack and ⅛ in. along the other edges of the slab. There is a circular hole drilled in the slab of wet gun-cotton to receive a small cylindrical disk of dry gun-cotton as a primer, and the position of this disk was marked by a circular hollow in the steel plate ½ in. deep in centre.

*C. Blasting or Mining Test in Brick-work.*—Three holes, each 1¼ in. in diameter and 18 in. in horizontal depth, were drilled in the solid brick-work of the counterscarp wall, and were respectively charged with 2 oz. of gun-cotton, blasting gelatin, and roburite; the holes were then tempered with loam in the ordinary manner, and fired by means of short lengths of Bickford fuze. The gun-cotton produced no apparent effect upon the brick-work, but Major Sale was of the opinion that the hole must have been open, or very weak, at the back. The blasting gelatin produced violent local action, displacing the brick through which the hole had been bored and the four adjacent to it. There was a slight bulge in the wall, the cracks extending radially from 10 in. to 12 in. The roburite exhibited a more widespread rending action upon the wall, the radius of disturbance being 15 in. or more, and the bulge being also greater. Rather larger charges of each explosive would have afforded a more satisfactory comparison.

*D. Ground Mines.*—Ten pounds each of gun-cotton, blasting gelatin, and roburite were loaded into holes in the bottom of the ditch 4 ft. deep by 8 in. in diameter, filled up with sand and slightly tamped. The explosion of these charges cast up tremendous fountains of loam and sand, and resulted in the following craters: Gun-cotton, 10 ft. 6 in. wide by 1 ft. 8½ in. deep; gelatin, 14 ft. 6 in. wide by 3 ft. 7 in. deep; roburite, 12 ft. 3 in. wide by 2 ft. 9 in. deep. The explosion of the gun-cotton mine appeared to cause great local action; but it will be

[illegible] charges. [illegible] greater [illegible] water with no [illegible] together. But [illegible] experiments, the great [illegible] to fit it for use [illegible] form would [illegible] stronger than any picric [illegible] the concussion of the [illegible] would be necessary [illegible] *Engineering*, 43,

[illegible] quoting from the [illegible] Russian explosive *

[illegible] 23, [illegible]

as Sleetover, and states that it is equal in strength to pyroxyline, and very cheap. "Another great superiority which it possesses over all the known explosives of the dynamite class is that when fired its force does not strike downward, but entirely in a forward direction, so that it can be used for all the purposes of cannon and musket charges to which ordinary gunpowder is now applied, without any damage whatever to the weapon from which it is discharged. It is stated, in fact, that ball cartridges loaded with it have been fired out of card-board barrels, as a test, without the least injury to the latter."

The "new Swedish explosive," bellite,* discovered by Mr. Carl Lamm, director of the Rötebro Explosive Manufactory, Limited, near Stockholm, consists of ammonium nitrate and dinitro benzene, which, when in a melted condition (the melting point is 80° to 90° C.), are mixed with saltpetre, forming a compound of which each molecule explodes. Bellite, when pressed warm, has a specific gravity of 1.2 to 1.4 in its granulated state, which, according to the experiments already made, seems to be the one best suited for military purposes. One litre of bellite weighs 800 to 875 grams.

Heated in an open vessel bellite loses its consistency at 90° C., but does not begin to separate before a temperature of 200° C. is reached; at that point evaporation begins, and increases with a higher temperature, without, however, explosion occurring. If the heating is sudden, bellite will burn with a sooty flame, something like tar; but if the source of the heat is removed, the bellite will cease burning and assume a caramel-like structure, the ingredients being the same as in its original state, with the exception of a somewhat reduced proportion of saltpetre. The explosive appears to absorb little moisture from the air after it has been pressed; if this operation is performed in the hot state, the subsequent increase of weight is only 2 per cent.

From the experiments of Werner Cronquist and Professor Cleve we learn that when bellite is subjected to the most powerful blow a man is capable of inflicting with a steel hammer upon an iron plate, it becomes heated, but neither explodes nor ignites. Two grains of bellite in a blank copper cartridge (that of a Remington rifle) were placed on an iron plate and subjected to the fall of a weight of 200 pounds from a height of 17 feet 6 inches, without exploding. Layers of bellite .47 inch in thickness on wood or iron have been pierced with rifle balls fired at a distance of some 50 yards, without showing

* Proc. Nav. Inst. 13, 247–248; 1887.

signs of exploding or ignition. While boring in cast iron with a steel drill, one grain of bellite has been placed in the hole, neither explosion nor ignition having resulted, although no sort of oil or other lubricator was used. A small quantity was fixed to the pointed end of a steel rod, and the rod knocked so hard against quartz as to produce sparks, yet there was no explosion. A good sized piece of bellite was placed in an open tin box and covered with gunpowder, the latter was ignited, the explosion throwing the bellite several yards in the air, but it did not explode. In a piece of hard wood a hole was made of the size of a penholder, two grains of bellite were pressed hard into the hole and this closed with a wooden cork. The wood was thrown into a coke fire and consumed, but there was no explosion. A compressed bellite cartridge was placed close to a rocky wall, and some three inches from it a cartridge of nitrolite (nitroglycerine, gun-cotton and nitrate of ammonia); the latter charge was made to explode by a Stubine percussion cap, and after the explosion the bellite cartridge was found to have been crushed, and the powder into which it was turned was fixed to the rock. The bellite had consequently not exploded. The list of these experiments might be considerably increased, but sufficient has been said to prove that bellite can withstand blows, fire, friction, and vibration, without the slightest risk of explosion. It can be safely transported by rail, and stored without any danger of spontaneous combustion.

Granulated bellite is caused to fully explode by the aid of a small quantity of fulminating mercury, even if its cover only consists of thin tin. When pressed warm, especially when it is in the form of hard cakes, it requires a stronger impulse and a stronger cover, which must adhere to the bellite.

The suitability of bellite as an explosive for gren
are provided with a proper percussion tube) has been
through a series of experiments carried out by officers of
Royal Artillery. A series of experiments has been made by ex
under water, mines loaded with bellite against a dynamome
average of several explosions gives, at a distance of 17 ft. 6 in.
of equal power to that caused by a weight of 22 pounds f
height of 39 in. At a reduced distance of 12 ft. 6 in. t
proportionately increased. On comparing the efficie
with that of gun-cotton, under exactly similar circu
former shows a superiority of 10.4 per cent at a distance of 17
in., and of 15.2 per cent at a distance of 12 ft. 6 in. The

millimetre machine-gun ammunition and steel bullets against mines loaded with bellite had not the least effect upon the explosive, thus proving it to possess a great advantage in this respect over other explosives generally used for submarine mines.

It is the opinion of those who have had the best opportunities of judging, and whose verdict is of acknowledged authority, that bellite bids fair to become of great importance; that it is equally suitable for mining and military purposes, while it is not so liable to be put to an undesirable use as are most other powerful explosives. (*Engineering*, **44**, 18, July 1, 1887.)

The press reports that an accidental explosion of melinite occurred at the arsenal at Belfort, March 10, 1887, by which six men were killed and eleven wounded. The *Army and Navy Journal*, May 14, states that in spite of this accident, and of a more recent one at Bourges, the belief in the new explosive is not abandoned, and that shells filled with it are to be tried against the Belligueuse, one of the early iron-clads, of 3617 tons displacement. The Germans, however, claim to have proved by experiment that melinite decomposes if kept long, and is therefore useless for war purposes.

U. S. Letters Patent No. 350048, September 28, 1886, have been granted to Eugene Dupont for a gunpowder press, in which two hydraulic rams, furnished with pins, work through each face of the mold plate. The result of this operation is that the powder in the apertures of the mold plate is compressed with equal force at both ends, and large grains of the desired dimensions and form (cylindrical or prismatic) are produced, in which the ends of the grains, being compressed with equally-moving pistons or rams, are both hard, while the central parts of the grains are comparatively soft when the grains are removed from the molding apertures. A grain of such construction, having two hard ends and a comparatively soft centre, is g[illegible] advantage in firing large ordnance, as it burns with great [illegible] the centre as well as the ends when once started, though [illegible]e of combustion is slow, owing to the compacted ends. [illegible]s is—

[illegible] for forming grains of explosive compounds, the com[illegible]d mold plate containing suitably formed apertures for [illegible]; two equally-moving and balanced rams acting [illegible] g[illegible]s from both ends, and pins passing through the

apertures in said mold plate and having a longitudinal motion therein independently of said rams, substantially as and for the purposes described.

U. S. Letters Patent No. 352611, November 16, 1886, have been granted Eugene Dupont for an explosive compound, in accordance with the following specification:

My invention consists in the use, in explosive compounds, of wood slightly changed in its chemical formula by the application of heat for the two purposes of increasing the ballistic force of the powder and of controlling the rate of combustion so as to adapt it for use in heavy charges behind projectiles of great weight, or to lighter charges in medium sized guns. With this end in view, I replace (either wholly or partially, as desired), the charcoal which is used in the composition of ordinary gunpowder, with the requisite amount of wood slightly changed in its chemical formula by having been subjected to heat or baked, as hereinafter described.

I have found that branch-willow wood is well adapted to the purpose; but any suitable wood for making gunpowder charcoal may be used.

I subject the wood to a gentle heat (either in a retort er fire, or by the application of superheated steam in a gradually raising the temperature to about 450° Fahr at the heat is maintained for about two hours (this would be fourths of a cord of willow), the entire time co t being about eight hours, six hours being consum in o proper temperature. The limits of temperature at ich t should cease (as far as I am now aware) to secure od r 300° Fahrenheit and 450° Fahrenheit, the lower perature the wood less rapidly combustible, and the higher sec a combustible wood. The process of heating the wood, should cease before the wood is transformed into red c is useless for my purpose, as red charcoal has entirely l t character of the wood, while in the wood which I invention the fibre is still undestroyed; and it is by br wood and examining if the fibre has been destroy that I a determine the point at which the baking should c e. 4 I heit is a temperature high enough to transform t charcoal, if maintained for a length of time; but I remo d before such transformation takes place.

My baked wood differs from red charcoal not only in its physical character by retaining its fibre, but also in its chemical formula. Red charcoal is considered to contain about 72.64 per cent of carbon, 4.71 per cent of hydrogen, 20.08 per cent of oxygen, and 0.57 per cent of ash. Although not a definite chemical compound, but being produced by partial decomposition, it will vary slightly in its formula. This also applies to my baked wood, which may vary even more than from 47.51 per cent of carbon, 6.12 per cent of hydrogen, 4.29 per cent of oxygen, and 0.08 per cent of ash, to 51.82 per cent of carbon, 3.99 per cent of hydrogen, 43.94 per cent of oxygen, and 0.22 per cent of ash; but, as will be seen, it has much less carbon than red charcoal, and still less than black charcoal. The carbon in my baked wood also retains to a certain extent, after being ground fine, its cellular form, and combines with the liberated oxygen from the saltpetre more readily than other forms of carbon, for instance, stone coal or lamp black.

The greater proportion of the oxygen and hydrogen in my baked wood than in charcoal is of very great importance to the ballistic effect of the powder. The theory of their action, as proved by experiment, is as follows: The temperature, after ignition of the charge in the gun, reaches 4000° Fahrenheit, a degree of heat too high to permit the oxygen and hydrogen to combine to form water, and they therefore must remain uncombined until, by the expansion due to the motion of the projectile toward the muzzle, these gases are cooled sufficiently to permit their union. When this takes place, a very large amount of heat is disengaged, which expands again the steam and other gases formed by the combustion of the powder. The pressure thus sustained while the projectile is in the gun insures a high velocity and a low pressure, because all the atoms of the powder cannot form new combinations at the time of ignition, but part of them unite as the pressure falls. It is therefore important to get as much of the substances containing oxygen and hydrogen in proportions to form water, or approximate proportions, into the powder as possible, and I therefore prefer the baked wood, which contains these gases in such proportions, besides having its carbon, as stated, in a form to unite readily with oxygen. The fibrous character of my baked wood also gives toughness to the grains of powder and prevents the grain from breaking up too rapidly.

It is unnecessary to describe the method of combining the components of powder, for that is well known, but I have found the following

ingredients and proportions to form a desirable powder for guns of twelve-inch calibre: saltpetre, seventy-eight parts, by weight; sulphur, three parts; baked wood, 12.5 parts; ordinary wood pulp, 2.5 parts; sugar (the use of which forms the subject of my application for letters patent, filed August 12, 1885, No. 174214), four parts; or, as I have also found the wood pulp may be omitted, as the grain will be toughened by the fibre of the baked wood, the proportions in this case being about as follows: saltpetre, 78.95 parts, by weight; sulphur, three parts; baked wood, 15.02 parts; sugar, 3.03 parts.

I do not limit myself to the special ingredients or proportions given above, as my invention consists in the combination of baked wood, as herein described, with well known gunpowder ingredients, and other equivalent ingredients may be substituted for those above mentioned.

What I claim is—

An explosive compound consisting of a nitrate and sulphur combined with charcoal retaining its fibrous structure, substantially as described.

In U. S. Letters Patent No. 363887, dated May 31, 1887, Eugene Dupont claims to have invented a new and useful compound, principally for use in guns of medium and large calibre, of which the following is a specification:

The first object of my invention is to obtain an explosive which shall have great ballistic force; and its second object is to obtain a powder which shall obviate, as far as possible, the many disadvantages pertaining in a greater or less degree to all artillery explosives, and which consists in the smoke arising from the burning powder, such smoke obscuring the view and interfering with the sighting for a second shot.

I have found by experiment that substances having c
nent parts the elements of hydrogen and oxygen in h
that, upon being released from the rest of the co
combustion, they will combine to form water and stea
increase the explosive force of the powder of which t
constituent element. The action of such powders s
follows: Upon firing the charge, the gases confined t p
are released, and act to expel by their expansion the
the muzzle of the gun. This I term the "first expl n."
time the oxygen and hydrogen are released as g b

great heat to unite in the form of steam. As the pressure is decreased by the motion of the projectile in the gun, this heat also decreases, and the gases—oxygen and hydrogen—unite in the form of water. The heat generated by this union at once changes the water into steam, and this expansion, which takes place before the projectile leaves the muzzle of the gun, I term the "second explosion." There is thus formed a powder of great explosive force, which acts twice upon the projectile. I have also found that such powders are very effective in dissipating the smoke arising from the discharge, owing, as I suppose, to the fact that the steam, generated as above stated, condenses, and in so doing absorbs large quantities of the carbonate of potash, the solid portion of the result of decomposition of a charge of powder and that portion which forms the smoke.

Thus I employ in place of the carbon usually used in the composition of explosive powders, the substances known as "carbohydrates," and which have the chemical formula of cellulose, $C_6H_{10}O_5$, or an approach to it, such as wood pulp, starch, dextrine, etc., or other substances, such as sugar, having substantially the chemical formula of $C_{12}H_{22}O_{11}$. All such substances having substantially the formulas aforesaid, and the capacity of forming water and steam by the action of the explosion, I term in this specification "carbohydrates." Instead of using one substance having the required chemical formula, two or more may be used having the necessary elements separate, which, when liberated, will combine to form steam and act in the manner required.

The materials should be mixed in a finely divided condition, and it is better to mix the carbohydrates with the other ingredients of the powder after such other ingredients have been mixed, as such carbohydrates are apt to be gummy in their nature.

I have found, for example, that a very effective powder may be made of the following substances, in substantially the proportions specified, viz., saltpetre (for which other known nitrates may be substituted) 78 parts, sulphur 2.8 to 3 parts, carbohydrates 3 to 4 parts, charcoal retaining its fibrous structure 12 or 12.5 parts. This powder, to be most effective, should be made in prismatic grains, and I have found that the best results are obtained by so constructing said grains that they are less dense in the middle than at the ends, which therefore have the particles more compacted together at those points than in the middle. My method of making these grains of such varying density is described in an application for letters patent,

filed August 12, 1885, Serial No. 167749. Such form and construction of the grains retard the development of the gases from combustion, until it is desired to obtain the maximum force; and I find that the fibres of the charcoal, retaining its fibrous structure referred to, materially aid in this result, as they tend to prevent the grains of powder from becoming broken up. The use of charcoal retaining its fibrous structure, as above referred to, forms the subject of an application for letters patent, filed June 5, 1885, Serial No. 167748.

What I claim is: 1. An explosive compound consisting of a nitrate, sulphur, charcoal retaining its fibrous structure, and a carbohydrate, substantially as described.

2. An explosive compound consisting of saltpetre, sulphur, charcoal retaining its fibrous structure, and sugar, substantially in the proportions specified.

From *Ding. Poly. Journal*, 263, 149; 1887, we learn that the composition of the brown prismatic powder sometimes known as cocoa powder is yet a secret, but it has been suggested that the charcoal used in its manufacture is made from peat, and the mysterious actions of the inventor tend to confirm this opinion. It is stated also that charcoal for this purpose is made at Chilworth and elsewhere by the action of superheated steam on rye straw.

We have frequently been asked to state to what the properties which distinguish the brown prismatic powder are due, and we trust it may not be considered out of place if we state our theory in this connection.

We hold that its property of imparting a high initial v projectile, while only exerting a relatively low pressure on the gun, is due to the combined action of a number of ca

1. The form of the grain; 2. the size of the grain; 3. t density of the grain; 4. the great hardness of the grain; 5. percentage of sulphur; 6. the easy inflammability of tl carbohydrates; 7. the relatively great heat evolved; 8. t of the chemical reaction.

Cause 5 tends to reduce the readiness with which p ignite, or raises its point of ignition, even when the g ized. Causes 1, 2, 3, 4, and 5 combined operate, so l four exist, to produce a very slow rate of combustion. By however, that the projectile is moved from its seat, the gr

reduced in size and more or less broken up. We shall then have a fine-grained powder which is highly inflammable at the temperature which exists (cause 6), and consequently the volume of gas evolved will increase rapidly as the volume of the chamber increases. Owing to the relatively great quantity of heat evolved (cause 7), the cooling effect of the envelope is less marked than with other powders. As the chemical reaction is a comparatively simple one (cause 8), the speed of the reaction is probably more uniform than when the reaction is more complex, as in other powders.

According to Berthelot, dissociation plays an important part. This is possible, and even probable, with powders made from underburnt charcoal, as this contains carbohydrates, or with those in which the carbohydrates are a constituent of the mixture.

The advantage of the form of grain employed was pointed out by Rodman,* the inventor, and his views have been confirmed by Sarrau.† The advantages of size, density (this is 1.86 in cocoa), and hardness are commonly known. Berthelot and Vieille ‡ have shown that the hydrates of carbon, such as cellulose, contain an excess of energy above that given by the carbon and water which their decomposition would furnish. And Noble states,§ in his lecture on the "Heat-Action of Explosives," that a unit mass of cocoa powder yielded a greater number of units of heat than any other of the standard powders, which Abel and Noble tested, yielded. He also shows ‖ that the chemical reaction attending the combustion of cocoa powder is simpler than that attending any other.

U. S. Letters Patent No. 362899, May 10, 1887, have been granted to Thorsten Nordenfelt, of Westminster, England, and Victor A. Meurling, of Christianstad, Sweden, in accordance with the following specification:

At the present time, in the manufacture of gunpowder, it is usual to incorporate the sulphur and saltpetre with the other materials by a process of grinding. This grinding is a dangerous operation after the saltpetre is added, and it has to be long continued in order that the mixture of the materials may be sufficiently intimate. Now, in place

* Experiments on Metals for Cannon and Cannon Powder, 291–297; Boston, 1861.

† Proc. Nav. Inst. 10, 160; 1884.

‡ Proc. Nav. Inst. 12, 187; 1886.

§ Heat in its Mechanical Applications, Inst. Civ. Eng. Lond., 211; 1885.

‖ Loc. cit. 209.

... A saturated
... The pulverized
... in bisulphide of
... in a closed vessel
... the mixture is complete, the
... aid of a gentle heat. The
... condensed, so that the solvent
... purpose may be such as are
... preparation of extracts and
When the bisulphide of carbon is evaporated, the

carbonaceous matter and sulphur remain intimately mixed, and each particle of carbonaceous matter has become impregnated with sulphur, instead of as at present, where the admixture is obtained by grinding, the particles of carbonaceous matter and sulphur being only mechanically placed side by side. The saltpetre is prepared for use by dissolving it in water, the solution is added to the pulverized carbonaceous matter already impregnated with sulphur as described above, and the whole is stirred together in a mechanical mixer.

We find it advisable not to add the whole of the saltpetre at one time, but to divide it into two or three separate quantities, and with each quantity we have sufficient water to render it sufficiently fluid for impregnating the carbonaceous matter already impregnated with sulphur.

After each admixture the water is separated by evaporation, and heat may be applied to hasten this evaporation, but in such manner as to avoid risk of the materials igniting as they become dry. After the first drying operation the material, in a state of powder, is again mixed with saltpetre solution, and it is afterwards again dried as before, and so for three or more times, should it be considered desirable to divide the operation of incorporating the saltpetre into so many operations. When the incorporation of the saltpetre is complete, it only remains to finish the powder for use by ordinary methods. It may be compressed into cakes or prisms, dried, broken up, and granulated in the usual manner.

By this method the dangerous process of grinding the powder after it has been rendered explosive by the addition of the saltpetre may be altogether avoided, or if in any case it should be considered advisable to resort to a grinding process after the materials have been mixed in the manner above described, the danger would be much less than at present, because of the lessened time during which the grinding would be continued.

The carbonaceous matter may also be submitted without risk to a grinding operation after the sulphur has been incorporated with it and before the saltpetre is added.

Although our invention is mainly intended for the manufacture of gunpowder from the ordinary ingredients, it is also applicable to the manufacture of like compounds in which the saltpetre is replaced by nitrate of soda or other salt capable of furnishing the oxygen to the carbonaceous matter and sulphur.

In the preparation of the cotton or vegetable fibre, liquid hydrochloric

acid may be employed; but the use of the gas, as herein described, is preferable.

Having thus particularly described and ascertained the nature of our said invention and the manner of performing the same, we declare that what we claim is—

1. As an improvement in the manufacture of gunpowder, the method described of incorporating the sulphur with carbonaceous matter, which consists in dissolving the sulphur in bisulphide of carbon, impregnating the carbonaceous matter with the solution so obtained, and separating the bisulphide of carbon by evaporation, substantially as set forth.

2. As an improvement in the manufacture of gunpowder, the method described of incorporating the sulphur and saltpetre or equivalent salt in the carbonaceous matter, which consists in dissolving the sulphur in bisulphide of carbon, impregnating the carbonaceous matter with the solution so obtained, separating the solvent by evaporating; also impregnating the carbonaceous matter with saltpetre or equivalent salt in solution, and separating the solvent by evaporation, substantially as set forth.

3. The hereinbefore described method of manufacturing gunpowder, which consists in treating cotton or equivalent vegetable fibre with hydrochloric acid (either gaseous or liquid) to obtain carbonaceous matter* with the sulphur and saltpetre, substantially as set forth.

From *Rept. H. M. Insp. Exp.*, p. 44; 1885, we learn that an explosion took place in a factory in which gunpowder was being made by Mr. Nordenfeldt's process. The accident was wholly due to carelessness, but the inspectors found that the presence of bisulphide of carbon in powder tends to sensibly lower the point of ignition.

U. S. Letters Patent No. 359289, March 15, 1887, granted to Edward Schultze, of Darmstadt, Germany, with the following specification:

The improvements in the manufacture of gunpow explosives consist in the composition and combi of of materials—of a nitro-hydrocarburet with pyroxyli l with a nitrate or salt, formed by the union of nitric d and furnishing a compound of oxygen and nitr hree constituents in various proportions I am a e to

* Proc. Nav. Inst. 8, 309; 1882.

an explosive of greater or less force. When this mixture is to be used as gunpowder for shooting purposes, I take a certain amount of the pyroxyline and diminish the rending force of the pyroxyline by adding nitro-hydrocarburets and nitrates; but when I wish to use said mixture as a blasting explosive, for blasting hard rocks or minerals and other blasting purposes, I augment this amount of pyroxyline with a view to producing greater rending force. When burning, these mixtures are free, or nearly, from noxious fumes, residue, and recoil. I instance, as belonging to the hydrocarburets which I employ in my mixtures, common resin or colophony, tar, turpentine, or turpentine oil, after having treated them with nitric acid. I instance, as belonging to the pyroxylines which I employ, nitro-cellulose (cotton or wood, or any vegetable fibre). I include the different varieties of pyroxyline, and instance the form commonly called gun-cotton. I instance as nitrates those of baryta, potassium or sodium, lime and ammonium. By different combinations of these constituents I am able to produce every class of explosives suitable for all purposes. I can use them, for instance, in the place of dynamite, for blasting hard rocks or minerals, treating the convenient mixture under hydraulic pressure; or in the place of black gunpowder, for blasting rocks or minerals less hard, or in the bombs and shells of the artillery. I can also employ my explosive as a filling for cartridges to be used in coal mines subject to fire-damp. These cartridges will not ignite the fire-damp, and thus obviate a fruitful cause of accidents. I can also choose another percentage in mixing the three constituents, so that the explosive is then suitable as gunpowder for sporting and military purposes.

I will now give examples of the proportions to be used in preparing explosives according to my invention, but I wish to be understood that they are given as the best proportions with which I am acquainted for carrying my invention into effect, and that I do not limit myself to the precise details given in these examples, as I can advantageously vary the proportions in the same manner as the black gunpowder-makers can and do vary their proportions of charcoal, sulphur, and saltpetre to produce explosives suited to various requirements.

The proportions hereinafter given are by weight. A powder suitable for sporting purposes can be made according to my invention by mixing twelve parts of nitro-tar, or colophony, or turpentine, or turpentine oil, or mixtures of them, with sixty to eighty parts of pyroxyline, sixty to eighty parts of nitrate of baryta, and eight to ten parts of nitrate of potassium.

This mixture is prepared and granulated in the well known manner prevalent in making black gunpowder. I may add some binding material or not, and the grains of the finished powder may be coated or not with substances fit for this purpose, such as paraffine, resin, or collodion.

Not more than five-eighths of this gunpowder for sporting purposes thus produced should be used in the place of the quantity of black gunpowder that is generally used for this purpose. The propelling force of the sporting powder thus produced is excellent, and the rending force is not greater than that of black gunpowder, and it is free or nearly free from objectionable fumes, residue, and recoil.

A good gunpowder for rifles is produced by mixing ten parts of nitro-tar, colophony, turpentine, or turpentine oil, or mixtures of them, with two hundred and eighty to three hundred parts of pyroxyline, one hundred to one hundred and twenty parts of nitrate of baryta, forty to fifty parts of nitrate of potassium, and about ten parts of sulphur.

This mixture is to be granulated in the same manner as the sporting gunpowder, and should be employed in quantities of about two-fifths the weight of the quantity of black gunpowder used for analogous purposes—such, for instance, as that for military rifles. The finished powder may be coated or not, as mentioned with respect to the sporting powder.

My blasting explosive, suitable for use in blasting mild rocks or minerals, has a little proportion of pyroxyline. I may also add to this explosive a quantity of sulphur.

The proportion of the materials may with advantage be parts each of pyroxyline and sulphur, fifteen parts of nitro burets, and seventy-five parts of saltpetre. The g tion of pyroxyline the greater will be the pov of t produced, so that when an explosive is requi for rocks or minerals, the proportion of pyroxyli should increased to suit the purpose for which it is ı uired.

Having fully described my invention, what I desire to secure by letters patent, is—

The composition, consisting of a nitro-hydrocarburet colophony, tar, turpentine, or turpentine oil), a of pyr 'trates or salts furnishing oxygen in combi ion oting and blasting purposes, substantially

According to the *Army and Navy Gazette*, **28**, 673; August 13, 1887, a series of trials has taken place at the Middlewick Ranges, Colchester, to test the relative merits of the Government cartridges, as loaded for the Enfield-Martini rifle, and others filled with a newly invented smokeless powder, which has been patented by Messrs. Johnson and Borland. The trial was carried out with a Gardner gun. The first trials consisted in firing 40 rounds of Government ammunition, so as to foul the barrel, and then 10 shots from the dirty barrel to test the accuracy. Although the gun had been well "laid" before the firing of the 10 shots, only 4 at 800 yards hit the target. The barrel was found to be very foul. The same number of shots were then fired with the "Johnson-Borland powder," with the result that in the last 10 of 50 rounds 8 struck the centre of the target. Then the barrels were inspected and compared and found comparatively clean. Indeed, once passing through the cleaning rod removed all residue, whereas it took 7 damped tows to clean the barrel in which the black had been fired. Trials for speed were then made, 40 rounds being fired in 5½ seconds. It was found that in consequence of the strain of the new powder being so small, the handle of the gun could be revolved with so much ease that the gun in rapid firing was not put out of position. The explosive force of the Government ammunition was such as to necessitate much more power being exerted in revolving the crank handle—a serious defect—whilst at the same time the "kick" was much greater. Besides this, the smoke from the Government ammunition was such that, after firing 20 rounds rapidly, the smoke accumulated so as to prevent No. 1 seeing through it; whereas with the new powder it was quite possible to see the bull's-eye at any time during the rapid firing. The velocity of the Government ammunition in the Enfield-Martini rifle is 1570 feet per second, which is the highest of any arm in the European service. With the new powder, 1800 feet per second has been arrived at. The experiments at Colchester show that the days are approaching when a smokeless explosive is likely to take the place of the present powder.

German Letters Patent No. 37631, October 14, 1885, have been granted to Friedr. Gaens, of Hamburg, for a gunpowder without sulphur, but which contains an ammonium salt, which will give rise to the formation of a potassium amine which is to be converted temporarily, at a higher temperature, into the explosive potassium nitride. (*Dingl. Poly. Jour.* **263**, 152; 1887.)

The *Scientific American*, p. 177, March 19, 1887, under the title Improved Gunpowder, states that A. H. Durnford has patented a process for making a soft charcoal which shall have an extremely low density, a low point of ignition, and slight hygroscopic properties, and which will produce a gunpowder possessing great energy and propelling power combined with moderate pressures when fired in a gun. The novelty consists in using charcoal made from cork by subjecting the cork to destructive distillation in cylinders at such a temperature as will produce the desired result. The gunpowder consists, first, of saltpetre and cork charcoal in the proportions of 80 to 20 respectively; second, of saltpetre, cork charcoal and sulphur, the latter being in proportions varying from 1 to 10 per cent. It is claimed that this powder is comparatively smokeless and non-hygroscopic.

It is now a well known fact that when compressed gun-cotton, dynamite, or other high explosives are freely exposed upon a metal plate and detonated, if the plate is sufficiently strong to resist rupture, the explosive leaves a marked and permanent impression upon the plate; the intensity of the impression being, of course, dependent upon the intensity and amount of the explosive used. This is not surprising when we recall that Berthelot found that gun-cotton having a density of 1.1 will develop, when in contact, a local pressure of 24,000 atmospheres or 160 tons on the square inch, and if we remember, too, that this enormous pressure is realized in an exceedingly brief space of time. The effect may of course be enhanced if the explosive be tamped with earth, water, etc. But, as Cooke* has so clearly shown in his essay on the "Air as an Anvil," the aerial fluid may serve as a tamp just as the aqueous one does, though not as efficiently.

It is perhaps not so well known a fact that the imp[illegible] by the exploding mass is an almost exact copy of t[illegible] surface of the explosive which was in contact with t[illegible] This feature is best observed with compressed gun-c[illegible] it is a *papier-maché*-like body, it is possible to sha[illegible] it and to stamp upon its surface such figures and desig[illegible]

The first recorded observation of this phenomenon of [illegible] aware, is that made by Lieutenant Max Von Förster, of W[illegible] a translation of his paper may be found in *Van Nostrand's* .

* Pop. Sci. Monthly.

**31**, 113, August 1884. He says that when a piece of compressed gun-cotton is detonated on a plate of iron, an accurate impression of the form of the under surface of the gun-cotton is produced. Every angle, every projection, and every indentation present in the gun-cotton is impressed on the underlying iron, and he claims that this is due to the fact that the gases acting on the iron have occupied exactly the same space and no more than the solid explosive previously occupied, and thus transferred its form, and hence he concludes that only the gases evolved by the very undermost layers of gun-cotton act on the iron, while the others are lost.

In *Van Nostrand's Eng. Mag.* **32**, 1, January 1885, we have given an illustration of similar impressions which we had observed previous to meeting with Von Förster's paper, and we advanced the opinion there, and subsequently in our Notes,* that it was due to projection, the residual gun-cotton being driven into the metal by the explosion of a portion of the original mass, just as any other resisting body interposed in the path of the explosive wave would have been. Of course we are met here by the difficulty that this hypothesis implies (1) that the pressure exerted upon the residual mass of gun-cotton is transmitted more rapidly than the explosive reaction is propagated within the mass, and (2) it implies also a great rigidity or coherency for this mass. The last condition requires that which is a property of masses of matter when moving at high velocities, as in the well known candle experiment, and in the cutting of steel by soft iron, and the like. The difficulties presented in the first condition do not seem so great as those in Lieutenant Von Förster's hypothesis.

Some months subsequent to this, Commander T. F. Jewell, U. S. N., read a paper before the American Association for the Advancement of Science, on "the apparent resistance of a body of air to a change of form under sudden compression," and presented as an example of this phenomenon an iron plate upon which a disk of gun-cotton had been detonated. The letters U. S. N. and the figures 1884 had been indented in the surface of the gun-cotton, and similar letters and figures were found indented in the plate. He held that this was due to the fact that the air enclosed in the letters and figures, under the sudden and enormous pressure to which it was subjected, acted like a hard body and was thus driven into the iron. This paper appears in the *Proc. American Association* **34**, 81; 1886.

In a later pamphlet (Berlin, 1886) Von Förster again states that the

* Proc. Nav. Inst. **11**, 110, Feb. 1885.

gases generated by the detonation of the gun-cotton have, in the first instant, and as long as they exert their maximum force, the exact form and occupy the same space as was occupied by the gun-cotton before detonation, and thus they produce an exact impression of the surface of the gun-cotton in contact with it. He also says that the suddenness with which the power is exerted is shown by placing a leaf between the gun-cotton disk and the iron, for, after detonation, the whole frame or skeleton of the leaf will be found raised upon the iron. He explains that this is due to the larger as well as the smaller ribs of the leaf protecting the underlying parts of the iron, while the thinner parts between could not yield such protection, and under them the impression is deeper.

This was the condition of the subject when we again took it up experimentally in 1886. We first detonated gun-cotton disks upon which the figures and letters were indented, and obtained impressions on the plates in which these were also indented. Next we used disks having raised letters and figures, and obtained impressions in which these were raised. Next we cut deep channels in the disks, of various forms, taking care that they always communicated with the outer air so that there would be no air confined in them, and again these indentations were exactly reproduced in the iron. Next we filled the indented letters and figures, in disks such as Jewell used, with paraffine and with vaseline, so that the material was flush with the surface of the disk, and on detonation the letters and figures were found to have been obliterated. Next we struck, with stamps, the same letters and figures in an iron plate. This plate was laid face downwards on another iron plate and a lettered gun-cotton disk placed on top and detonated. The result was that while the gun-cotton disk produced the usual indented letters on the back of the top plate of iron, the top plate in whose letters and figures air was also confined and which was subjected to the same blow, produced raised letters and figures on the bottom plate on which it rested. These last three experiments certainly seem to prove that the air has nothing to do with this action. Again, when we consider how enormous the pressure is to which this air is subjected we must believe that, no matter how suddenly the force is applied, the air must undergo some compression, yet we find that the indentations in the iron are often nearly as deep as those in the gun-cotton.

In considering Von Förster's hypothesis, we are l that the gases at the time of detonation possess the e :l

occupy the same space as the gun-cotton from which they are formed, if the change takes place instantaneously. But it does not; in fact, it occupies so appreciable a period of time that the rate of propagation of the detonation in it has been measured. Apart from this, and even granting it, it will be observed that Von Förster does not explain how the impression is to be produced by the gas. If the gas moves as a solid body, then the impressions should be the reverse of what we get.

From our experiments we are the more strongly convinced that the effect is a purely ballistic one, and that while the base of the gun-cotton, or its products, are projected as a whole against the plate, where the intervening spaces are the greatest there we have the greatest effect of impact, and consequently the greatest indentation. This is true in the leaf experiment, which has been exquisitely reproduced. The varying thicknesses of the leaf vary the distances through which the material is projected, and hence the form and texture are reproduced in the impression.

These experiments were described before the *Am. Assn. Ad. Sci.* in August, 1887, and the plates exhibited there have been very accurately and beautifully represented in the *Sci. Am.* 57, 223, October 8, 1887; but the editorial description is inaccurate in some particulars. In the same paper are illustrations of the application of gun-cotton for testing the resistance of metals to shocks, as described in these Proceedings.* It should be stated that this method gives a means for revealing the inner structure of metals in masses such as we have never before possessed.

A new way of utilizing dynamite has been lately devised by a French military engineer, M. Bonnetond. He uses the expansive force to drive out, for a brief period, the water from portions of wet ground in which foundations are to be made. The method is now in practice in the construction of a fortified *enceinte* at Lyons. A hole is first bored 10 or 12 feet and about 1½ inches wide in the wet ground. Into this is passed a string of cartridges of dynamite, which is then exploded. The water is thus driven far out beyond the sides of the cavity, over a yard wide, which is produced, and does not reappear till after half an hour at least. The workmen thus have time to clear the cavity and introduce quickly-setting concrete. When the water returns it cannot injure the foundation. A rapid rate of progress is realized by this method. (*Nature*, 36, 564; 1887.)

* Proc. Nav. Inst. 13, 116; 1887.

The *Boston Globe*, July 22, 1887, notes that the balloon department of the German army is experimenting with a view to trying the destructive effect of dynamite hurled down upon forts from a balloon. In the *Sci. Am.* p. 181, March 19, 1887, W. Maxwell Maynard proposes that large fire balloons, to which a charge of dynamite is attached, be sent up among the rain clouds and discharged there in order to precipitate a rainfall in dry weather.

A new method of blasting without explosives has been recently introduced by Dr. Kosman, and is described in *Jour. Inst. Civ. Eng.* 87, 41. Zinc powder and sulphuric acid are contained in a glass cartridge, by breaking which the two substances are brought in contact and hydrogen is rapidly evolved. A pressure of about 37,000 atmospheres is obtained, although, perhaps, with hardly sufficient rapidity to justify the use of the term explosion. (*Engineering*, 43, 67, Jan. 21, 1887.)

A. Cavazzi, *Gazzetta Chimica Italiana*, in studying the reduction of potassium nitrate by various substances, has found that a mixture of equal parts of the nitrate and sodium hypophosphite detonates violently when heated to about the fusing point of the mixture. Other proportions yield explosive mixtures, but the above are the best. (*Sci. Am.* p. 181, March 19, 1887.)

H. N. Warren states in the *Chemical News* 55, 289, June 24, 1887, that he has probably obtained "Fluoride of Nitrogen" or fluoramide, by passing an electric current from seven ferric chloride batteries through a concentrated solution of ammonium fluoride. After a lapse of a short time, several drops, of oily consistence, were observed attached to the negative plate. On becoming connected with the positive, a thin gold wire, these drops exploded with great violence. The compound is undoubtedly highly unstable, being at once decomposed in contact with glass, silica, or organic matter, thus rendering the analysis one of considerable risk. Its explosive violence is even greater than that of the chloramide, and it is also prone to spontaneous decomposition.

There was recently a prosecution, before one of the P c of the agent of a banking house in Berlin, for jeo dy train of railroad cars. The main question was whetl d could, under the circumstances, occasion sponta

which, after hearing the testimony of the court's expert chemist, Dr. Jeserich, was decided in the affirmative. The agent had sent ten kilos (22 pounds) of fuming nitric acid from Berlin, intended for some point in Bavaria, per railroad. The acid was contained in a strong stone jar, tightly closed by a stone stopper and cement. The whole was packed in straw within a wooden case. Since such corrosive and dangerous liquids would not be transported by railroad as express freight, the contents of the box were represented to be clothing, and by this means the concealed acid was sent by a passenger train. During the journey, and when near Butterfeld station, the car containing the express freight was discovered to be on fire.*

Before the flames had made serious progress, the car was uncoupled and switched off on a side track, and the fire extinguished with comparatively slight damage, and no person was injured. Examination showed that the jar had leaked, and the acid had come in contact with a roll of woolen cloth, whereby the latter was set on fire. Dr. Jeserich gave it as his opinion that all woolen goods and all hair of animals, horn, etc., have the property of igniting spontaneously when coming in contact with fuming nitric acid; and he stated that all new explosives, about which there had been so much said and written lately, such as roburite, melanite, etc., are produced by the action of nitric acid on hair and wool. Herr Lack, the agent who made the misrepresentation about the acid, was condemned to two months imprisonment. (*Sci. Am.* **57**, 260, 1887, Abstr. *All. Vers. Presse*, Berlin.)

When preparing hypochlorous anhydride by the usual process, A. Mermet used liquid methyl chloride as a refrigerant instead of snow and salt. A violent explosion took place, the apparatus being destroyed and the assistant in charge had the lobe of his right ear torn. This catastrophe is ascribed to the vapors of the two liquids coming in contact. (*Chemical News* **55**, 249, May 27, 1887, Abstr. *Bull. Soc. Chim.* **47**, March 5, 1887.)

*Scribner's Magazine*, **2**, 197–221, August 1887, contains an interesting article by N. S. Shaler on the "Instability of the Atmosphere," in which the destructive effects produced by a sudden rush of gas are well described, and illustrated by numerous photographs. In speaking of the tornado he says that in its path over the surface, the circling movement of the writhing air and the sucking action of the partial

* Proc. Nav. Inst. 8, 311; 1882, and 9, 753; 1883.

vacuum in the central portion of the shaft combine to bring about extreme devastation. On the outside of the whirl the air, which rushes in a circling path toward the vortex, overturns all movable objects, and in the centre these objects, if they are not too heavy, are sucked up as by a great air-pump. Thus the roofs of houses, bodies of men and animals, may be lifted to great elevations, until they are tossed by the tumultuous movements beyond the limits of the ascending currents and fall back upon the earth. Where the centre of the whirlwind passes over a building, the sudden decrease in the pressure of the outer air often causes the atmosphere which is contained within the walls suddenly to press against the sides of the structure, so that these sides are quickly driven outward as by a charge of gunpowder.

It is not unlikely that the diminution of pressure brought about by the passage of the interior of the whirl over a building may be about as much as is indicated by the fall of four inches in the barometer. This is equivalent to a change in the pressure amounting to about 300 pounds to the square foot. This force operates to burst out the walls of a building. It is not improbable that the diminution of pressure may be much greater than this, but the amount named is sufficient to produce many of the effects noted.

These effects may be compared with those produced by the discharge of heavy ordnance or the blasts from high explosives.*

G. Masson, Paris, announces, in June 1887, the publication of Les nouveaux explosifs et la fortification, by le commandant Mougin.

* Proc. Nav. Inst. 13, 408; 1887.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

October 27, 1887.

Lieutenant Austin M. Knight,* U. S. N., in the Chair.

# ALUMINUM BRONZE FOR HEAVY GUNS.

By Alfred H. Cowles.†

*Mr. Chairman and Gentlemen*:—The Government of the United States is equipping its fortifications and navy with new guns. Can we not improve upon the present armaments of Europe, instead of imitating them? If so, it is certainly an achievement worth striving for. I will endeavor to show that, with certain alloys of aluminum, we can increase *the life and destructive power, and diminish the cost and weight.*

How near can we approach to the requirements of a perfect gun metal? Assuming the carriage takes up the recoil, an ideal or perfect gun may be described as a gun of minimum weight and simplest construction, which shall be able to resist a maximum internal pressure in order to produce a maximum effect. Such a gun must be of one piece, in order to act like a great spring; it should respond very stiffly to the pressure of the powder gases, always perfectly recovering its original form; and its walls should be hard enough to withstand the abrasive action of the projectile. It is impossible to attain perfection. For safety, this great spring should have the property of stretching much beyond its elasticity,—thereby danger of violent explosion will be avoided. In practice, a gun must be considered a temporary structure. Its value is measured by its destructive power and its life, as related to its cost and its weight.

In order to make the nearest approach to the ideal gun, we must study the physical properties required of the metal to be used in its fabrication.

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† The author desires to give his brother, Mr. Eugene H. Cowles, due credit for much valuable assistance in the preparation of the following paper.

First, to withstand a high pressure of the powder gases, the metal around the bore of the gun must have as high an elastic limit as attainable, as it is this property that determines the pressure a gun will stand without distortion.

Second, and perhaps of greater importance, the distance the metal will stretch within its elastic limit, and yet perfectly recover itself, should be as great as possible. This gives the gun the character of a spring. To illustrate: If we take two guns made of different metals, the elastic limit of the metals in each case being the same, but the elastic extension of one being twice that of the other, the latter gun will have twice the power to resist heavy shocks, as it will act in resisting them with the same force through twice the distance.

Third, the metal of a gun should be as ductile as possible; and this ductility must be obtained without sacrificing a high elastic limit and elasticity, especially in the metal immediately surrounding the bore. As it will be shown later, this can be accomplished. The metal around the bore can be made to have great elasticity and a high elastic limit, and that of the outer portions of the gun great toughness. In 1865 Sir Wm. Armstrong stated that not one of 3000 wrought-iron "built-up" guns had burst explosively. Here he labored under the disadvantages of building up the guns, and using a metal of a low elastic limit and low elasticity; but clearly proved the value of great ductility.

Fourth, hardness in a gun metal has ceased to be one of the principal requirements. It is, however, desirable in a metal designed for the smaller sized cannon. It has been quite clearly demonstrated that a steel tube with thin walls can be inserted in the bore of a large gun, and made to withstand the destructive effect of the ball and the powder gases. When once destroyed it can be renewed at small expense.

With these points in view, we shall now proceed to discuss some of the difficulties that have arisen in the fabrication of large steel guns, and see if they cannot be overcome by the substitution of aluminum bronze or some of the other alloys of aluminum.

In this brief article I need not refer to the many recorded failures [illegible] and the known instances of cast-iron guns surpassing [illegible] and approaching it in destructive power. The steel gun of to-day is built up of an aggregation of hoops and tubes, [illegible] upon the other, in a vain attempt to carry out Mr. Blakely's splendid conception of a gun so constructed that initial tensions of the metal shall vary from the centre outwards

in order to correspond exactly with the variation of strain thrown upon its different parts at the moment of explosion. To accomplish this satisfactorily by building up a gun is generally conceded to be a mechanical impossibility. It is theoretically impossible to realize all the strength of the metal.* Mr. Longridge has mathematically demonstrated that in an 8-inch gun, twenty-three and six-tenths inches in diameter, composed of four rings *perfectly* fitted together, only 80 per centum of the full strength of the metal can be utilized. He has further shown that a mechanical deviation of one two-thousandths of an inch in the proper tension of a ring seventeen inches in internal diameter will render the condition such that this gun is no stronger than it would be were the metal in repose. This calls for such nicety in the work of building up a steel gun that practical men consider it impossible. A failure to learn the exact elasticity of the great masses of metal, variations in their elasticity, variations in their contraction during cooling, a dulled tool—any one of these causes would be sufficient to make such a small mechanical deviation as the above, which could readily pass unnoticed.

Again we have in a "built-up" gun the destructive effect of vibration. Alexander Holley† makes the following illustration. If an armor plate, built of a number of layers which are not fastened or welded together, be struck by a shot, two kinds of motion will be imparted to it: one tending to drive the plate bodily forward, and the other a wave motion, passing through the plates with a velocity about equal to that of sound through the metal of which the plates are composed. The layer struck will for an instant be reduced in thickness and extended in its other dimensions. When it recovers its original form by its elasticity, it will have in turn compressed the next layer, and so on until the last layer receives the shock. The inertia of this last plate tends to hold it in place until it is compressed. It is then in the condition of a spring, pressing equally in both directions, and resisted by a heavy mass on one side, but only by its own weight on the other, so that it jumps violently to the rear, tending to cause rupture or distortion. Were the plate solid, this tendency to separation would be overcome by the cohesion of the whole mass of the metal. In a "built-up" steel gun the tendency to this phenomenon is the more marked, as the external layers of metal are already under tension, and but a small wave motion is required to cause the metal to pass its elastic limit and cause distortion or rupture.

* See Alexander Holley's "Ordnance and Armor," pp. 248, 249.

† Holley's "Ordnance and Armor," p. 281.

Another evil, due to vibration, is exaggerated in a "built-up" gun. I refer to crystallization of the steel. To illustrate: It is well known that if a bell be made of two parts nicely joined, it will not give a musical note, but instead a deadened noise. This is due to the fundamental vibration being destroyed by the break in the metal, and the new vibrations formed interfere with one another, producing nodes and discord. A solid gun is to the "built-up" gun as a perfect bell is to the one described. By the present practice, when a gun is discharged, the inner layer of metal is distended almost to its elastic limit. This wave of distension passes outward, and is immediately superseded by a great number of reflections. These reflections are multiplied by the number of layers of metal in the gun, and their directions are governed by all variations in the form of the various parts. The amplitudes of vibrations of all these waves are greatest near the tube of the gun. Although the intensity of the fundamental wave is not great enough to stretch the metal beyond its elastic limit, whenever several of these reflections cross one another, the amplitude of the resultant becomes so great that the metal is either distorted or ruptured locally, and internal crystallization takes place.

Considering this fact, it would appear that the damaging effect is proportional to the square of the number of internal surfaces. In a tube or gun having homogeneous walls of uniform external and internal diameter, a vibration of the nature we started with would simply pass from the inner surface to the external and back again, and so continue until its energy was changed to heat or transmitted to the air, its waves of tension never interfering with their own reflections, so as to distend the metal beyond its elastic limit or tenacity and thereby cause crystallization. Hence it is, that if the nicely calculated adjustment of internal compression and external tension is ever attained in practice, experience has demonstrated that forming the gun of so many parts destroys the result attained, after a small number of discharges. These causes explain what is now called the "phenomenal endurance" of the cast-iron smooth-bore guns and of the converted rifles, and the fact, as I am told, that the Krupp Company will only guarantee their "built-up" steel guns to stand seventy-five service charges. Our Government has the record of several hundred 10-inch cast-iron guns converted into 8-inch rifles, no one of which has ever failed.

In order to learn further the efficiency of a solid gun as compared to a "built-up" gun, we shall compare the powder pressure attained in practice in cast-iron guns with that attained in steel guns. It is [illegible] that the cast-iron guns are now lined with steel or wrought-iron

tubes; their endurance, however, was equally marked without the tubes when quicker burning powder was used. On the other hand, the "built-up" steel guns are *supposed* to have the strength of their walls further developed in them by the principle of varying initial tension. The strength gained by this should be equal to that gained (due to the tube) in the cast-iron guns, and render our comparison fair.*

At the present day, with service charges, cast-iron guns have as an average about fourteen and five-tenths tons pressure to the square inch of surface of the bore at the moment of explosion. This is about equal to the tensile strength of cast iron. With steel guns the pressure is about twenty tons, or only forty-seven per centum of the

* Table showing the pressure of the powder gases in guns of similar calibres of steel, wrought iron, and cast iron; compiled from the table on page 100 of the Report on Heavy Ordnance and Projectiles: Logan Committee, 1883.

| | Calibre | Weight. | Length. | Twists in number of calibres | Powder Charge. | Weight of Projectile. | Initial Velocity. | Pressure per square inch of bore. | Penetration of iron at 1000 yards |
|---|---|---|---|---|---|---|---|---|---|
| | Ins. | Tons. | Ft. | | Lbs. | Lbs. | Ft. | Tons. | Ins. |
| STEEL GUNS. German, from Essen. . L. cannon of steel and steel hooped.—Krupp. | 15.75 | 71 | 32.8 | 1 in 45 | 484 | 1718 | 1703 | 20.9 | 31.81 |
| " " " | 13.97 | 51 | 29.13 | 1 in 45 | 253 | 1155 | 1642 | 22. | 24.97 |
| " " " | 12. | 36 | 22. | 1 in 72 | 143 | 664 | 1517 | 19.5 | 26.12 |
| " " " | 15.75 | 71 | 32.8 | .. | 462 | 1760 | 1695 | 16.90 | 25. |
| | | | | | Average Pressure, 19.82 tons. | | | | |
| WROUGHT-IRON GUNS. M. L. coiled wrought-iron cannon, tube of cast steel.—English, Elswick | 17.72 | 100 | 30.9 | 1 to 150 to 1 in 90 near muzzle. | 463 | 2010 | 1640 | 21 | 25.88 |
| M. L. coiled wrought-iron cannon, tube of cast steel.—English, Woolwich | 12.5 | 38 | 18.75 | From 0 to 1 in 35. | 800 | [illegible] | 1590 | 21. | 17.97 |
| B. L. coiled wrought-iron cannon, tube of cast steel.—Woolwich | 12. | 43 | 27.75 | .. | 311½ | 700 | 1950 | 18.7 | 20.01 |
| M. L. coiled wrought-iron cannon, tube of cast steel.—Frazer's System | 16. | 80 | 26.9 | .. | 460 | 1760 | 1606 | 20.5 | 22.23 |
| | | | | | Average Pressure, 20.05 tons. | | | | |
| CAST-IRON GUNS. B. L. cast-iron cannon, hooped with steel.—General Rosset's System, Italian | 18.1<br>12.6 | 87<br>38 | 29.52<br>22.5 | 1 in 60<br>1 in 70 | 440<br>158 | 2000<br>770 | 1376<br>1492 | 15.8<br>10.6 | 14.23<br>16.69 |
| M. L. cast-iron, lined with coiled wrought-iron tube.—U. S. | 10.25 | 40 | 21.82 | 1 in 70 | 115 | 700 | 1485 | 15. | 15.75 |
| B. L. cast-iron, hooped with steel. Italian, Turin | 17.72 | 100 | 30.8 | 1 in 60 | 485 | 2004 | 1512 | 14.5 | 23.87 |
| M. L. cast-iron rifle, converted from 15-inch Rodman. At Sandy Hook fired 401 rounds.—U. S. | 11. | 24.5 | 16.6 | 1 in 39.8 | 90 | 543 | 1280 | 14.68 | 13.50 |
| | | | | | Average Pressure, 14.51 tons. | | | | |

tensile strength of gun steel. In other words, with a strength of metal *three times as great*, *only thirty-three per centum increase in efficiency* is obtained in a "built-up" steel gun over one of solid cast iron, and the latter has *far greater endurance.*

It must be understood that these pressures are average results. Cast-iron guns have repeatedly been known to stand pressures far above the tensile strength of the metal without apparent rupture, but it is doubtful whether a steel gun has ever stood such a test.

In Table I. we have the average physical properties of the metals now used in the fabrication of guns.

Table II. gives us a slight insight into a field of aluminum alloys which up to the present time has scarcely received investigation. On the testing machine at the works of the Cowles Electric Smelting and Aluminum Company, at Lockport, N. Y., higher results have been obtained, and other alloys made in small quantities whose physical properties have surpassed these.

TABLE I.

*Physical Properties of Gun Metals now used.*

| Metal. | Elastic Limit | Elastic Extension per unit length. | Tensile Strength per square inch of original section. | Elongation per centum after rupture | Contraction of Area per centum. | Modulus of Elasticity. | Compressive Strength per square inch. | Hardness U. S. Standard. | [illegible] |
|---|---|---|---|---|---|---|---|---|---|
| | Lbs | | Lbs. | | | Lbs. | Lbs. | | |
| STEEL. Average properties of 137 specimens of accepted gun steel from hoops, jackets, and tubes, oil tempered and annealed U S Government tests .. ........ | 51,611 | 0.00207 | 96,150 | 19.93 | 43. | About 29,000,000 | .... | [illegible] | [illegible] |
| Same grades of steel not oil tempered and annealed, average of 19 specimens. ..... . | 38,140 | 0.0016 | 88,000 | 18.7 | 37. | .... | .... | [illegible] | [illegible] |
| Cast gun steel, German soft (Alexander Holley, "Ordnance and Armor") ..... .. .... | 35,392 | 0.00096 | 70,784 | .... | ... | .... | [illegible] | .... | [illegible] |
| WROUGHT IRON FORGINGS. | | | | | | | | | |
| Small bars { Highest ... | 30,000 | 0.0016 | 73,000 | | .... | .... | 80,000 | .... | [illegible] |
| Small bars { Mean . . | 18,000 | 0.00065 | 53,000 | 26. | | | | | |
| Heavy forgings, average of 700 tests at Sir Wm Armstrong's works..... | 23,760 | .... | 48,160 | .... | .... | .... | .... | .... | [illegible] |
| CAST IRON. Average of four Watertown tests of accepted iron .. ...... ..... . | 17,000 | 0.0009 | 30,000 | 0.266 | nil | .... | [illegible] | [illegible] | |
| GUN BRONZE. [illegible]rage of fourteen [illegible]own tests .. .... | 13,214 | 0.0012 | 38,995 | 33 6 | 33 [illegible] | .... | [illegible] | | |

## Table II.

*Physical Tests on a few Aluminum Alloys.*

| Alloy Tested. | Diameter in inches | Cross Section in square inches. | Length between marks in inches | Elastic Limit, pounds per square inch | Elastic Extension per unit length | Tensile Strength, lbs., per square inch of original section | Elongation per centum | Contraction of Area, per centum | Hardness | Modulus of Elasticity. | Specific Gravity | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $A_1$ Bronze, old name Special Composition, Cu 89, Al 10, Si 1 | 0.5 | ..... | 2 | ...... | ..... | 114,51[illegible] | 4.[illegible] | 0 | . | .... | 7.56 | Washington Navy Yard Tests, Feb. 10, 1886. |
| | 0.501 | ..... | 2 | 69,749 | ..... | 95,366 | 0.5 | .6 | ... | .... | | |
| | 0.501 | ...... | 2 | 79,894 | ...... | 109,823 | [illegible].5 | 2.39 | . | .. .. | . | |
| Bars cast in sand. Maximum strength sought | | .0646 | 1 | ...... | .. .. | 128,000 | .0 | 0 | . | .. | | Tests 1 at Leeds Forge, England. |
| | 0.304 | ..... | 1 | ...... | ...... | 97,380 | .0 | | . | ...... | .. | Watertown Testing Machine, July 11, 1887 |
| | 0.315 | .. ... | 1 | ...... | ...... | 115,260 | . | . | . | ... | | |
| | 0.272 | ..... | 1 | ..... | ...... | 118,59[illegible] | [illegible] | .. | | .... | | |
| * $A_1$ Bronze, forged at red heat | .798 | .5 | 10 | 38,000 | 0.00237 | 81,700 | 5.2 | 11.4 | | 17,544,000 | . | Watertown tests, April 29, 1887 |
| | .798 | .5 | 10 | 41,000 | 0.00259 | 87,000 | 2 | 8.6 | | 17,241,000 | | |
| $A_2$ Bronze, cast in sand | .321 | .0809 | 1 | ..... | ...... | 87,51[illegible] | 17. | .. | .. | ..... | 7.65 | Watertown tests, July 11, 1887. |
| $A_2$ Bronze, forged | .503 | .199 | 2 | ...... | .... | 83,82[illegible] | 35.5 | 43.2 | . | . | | |
| $A_3$ Bronze, Composition Cu 91¾ per cent, Al 7½ per cent, Si ¾ per cent. Cast in chill mold | | 1. | 6 | 21,500 | 0.00133 | 69,800 | 32.8 | 32.1 | 13.46 | 16,52[illegible],000 | 7.8 | Watertown, July 11, 1887. |
| | | 1. | 6 | 24,000 | 0.0018 | 68,000 | 18.2 | 20.1 | 11.8 | 16,300,000 | | |
| | .312 | .... | 1 | ...... | ..... | 74,770 | 25. | .. | .. | ..... | | Watertown, July 11, 1887. |
| | .327 | ...... | 1 | ...... | ...... | 68,930 | 48. | . | . | ..... | . | |
| | .327 | ...... | 1 | ...... | ...... | 71,790 | 40. | ... | .. | ..... | .. | |
| Aluminum Brass No. 1. Composition 71¾ per cent Cu, 3¼ per cent Al, 25 per cent Zn. Cast in chill. | | 1. | 6 | 21,500 | 0.0018 | 63,450 | 11.2 | 23. | 9.2 | 14,070,000 | .. | Watertown, July 11, 1887 |
| Aluminum Brass, No. 2. Composition Cu 63⅓, Al 3⅓, Zn 33⅓. Chill casting | ...... | 1. | 6 | 47,000 | 0.0091 | 76,8[illegible] | 3.5 | 8.4 | 12.6 | 13,400,000 | | Watertown, July 11, 1887 |
| Small bars cast in sand. Made by Electric Co. | .306 | .... | 1 | ...... | .... | 91,5[illegible] | 9 | 1.4 | | | | Watertown |
| | .296 | . .... | 2 | ...... | ...... | 88,050 | 4. | 7.3 | . | ... | | |

* Compression tests of $A_1$ forged bars 2" x .798" diameter, 160,400 lbs. to the square inch and 153,600 lbs. to the square [illegible] Watertown, A[illegible] 1[illegible]7

With alloys of these physical properties at command, which can be cast more readily than cast iron, there are two well-tried methods of fabrication that might be employed to give us *solid* guns of great destructive powers and endurance.

First, the Rodman method of casting a gun, and cooling it from the centre during the solidification of the metal. Were this employed, we might adopt the $A_1$ bronze, having a tensile strength of about one hundred thousand pounds to the square inch, a hardness greater than cast iron, and an elastic limit four times as high. The extension within the elastic limit is over three times that of cast iron; hence, its power to resist shocks would be, as compared to a cast-iron gun, proportional to the products of the elastic limits of the two metals into their elastic extensions, or about as twelve is to one. We should still have some ductility in reserve, which cast iron has not. In casting aluminum bronze by Rodman's method, we should be enabled to overcome one very serious difficulty that existed in casting iron guns. The temperature at which this grade of bronze solidifies is only about sixteen hundred degrees Fahrenheit, as compared to twenty-seven hundred degrees, the melting temperature of cast iron. With this low temperature, we could heat the outside of the mold as hot as the molten metal, and thereby cause all cooling to take place entirely from the centre, which we know would be the ideal perfection of the Rodman method of casting guns.

The destructive effect of heat upon gun bronze is a serious objection to the use of that metal. An interesting experiment, performed by Lieutenant M. E. Hall, U. S. N., and myself, illustrates the peculiar fitness of this grade of aluminum bronze to overcome this difficulty. There were cast two bars of $A_1$ aluminum bronze, attached to the same gate in the sand. One, on testing, developed one hundred and nine thousand one hundred and twenty pounds tensile strength to the square inch, and five per centum elongation. The duplicate was then placed in the machine and strained till it was resisting one hundred thousand pounds stress. It was then heated by a blowpipe flame to a temperature at which cotton waste would char when placed against the bar (about 400° F.), and while so heated the strain was increased to one hundred and seven thousand pounds to the square inch. It was then allowed to cool down to the ...ature of the room and again tested, when it stood one hundred ... thousand one hundred and sixty-two pounds to the square ...out breaking. On heating the bar again to the temperature

of charring waste, it broke at eighty-six thousand pounds, and had developed about four per centum elongation. We concluded that its finally breaking at a lower tensile strength than it had already stood in stress upon it, under apparently the same conditions, was either due to an inequality in the temperature, or to the fact that the strain of one hundred and ten thousand pounds had caused a partial rupture. From this experiment we became fully convinced that this grade of bronze retained its remarkable strength through a great range of temperature.

The second, and probably the best method to follow in the fabrication, is one invented by the late Samuel B. Dean, of Boston, which is now used in making cannon from tin bronze.* In Great Britain, in 1870, the Committee on Field Artillery for India reported in favor of and adopted this method. Our Government Ordnance Bureau ordered guns to be made by the Dean process in July, 1870, and the work was subsequently interrupted in consequence of the neglect of Congress to vote the necessary funds. The Austrian artillery adopted the process in 1873, and since then have used it exclusively. The credit of the invention is there given to General Uchatius. The gun is first cast solid in a chill mold. It is then bored, and conical chilled steel mandrels of gradually increasing diameters are successively driven through the bore by hydraulic pressure. The metal around the bore is thereby given greater strength and hardness, a higher elastic limit, and a greater elastic extension. These properties gradually vary till the outer circumference of the gun is reached, where the metal has its normal condition of great toughness. An exhaustive series of experiments made by General Uchatius resulted in the selection of a bronze for a gun so constructed containing ninety-two parts copper and eight parts of tin, this being the copper tin alloy having the greatest combination of strength and ductility. Cast in a chill to cause the tin to form a homogeneous alloy with the copper, he obtained the following properties:

| | |
|---|---|
| Tensile strength, . . | 43,200 pounds to the square inch. |
| Elastic limit, . . . . | 5,672 " " " |
| Elastic extension, . . | 0.0004 per unit length. |
| Ultimate elongation, . | 40 per centum. |
| Hardness, . . . . . | 5. |

* See pp. 530 to 540, Part 3d, "The Materials of Engineering," by Robert H. Thurston, A. M., C. E.

[illegible] metal in the bore could be [illegible] pounds to the square inch. [illegible] seventy thousand pounds. [illegible] increased, and, as other [illegible] surpass that of gun steel. [illegible] the strain is not as great at the [illegible] *great reserve of ductility.* It [illegible] with four times the powder [illegible] gun. The walls would [illegible] *of crystallization. No rust* [illegible] bronze. The finished gun would [illegible] It would not be affected by salt [illegible] guns would not require a great outlay [illegible] and the mineral resources of our country [illegible] inexhaustible quantities the raw material [illegible] of the aluminum alloys. Were our [illegible] a great advance in the art of gun [illegible] itself with the guns now needed, it [illegible] against us, the present armaments of Europe. [illegible] to be considered, viz., the cost of alum- [illegible] compared to steel guns. In the following table [illegible] average cost of steel guns in Europe is about fifty-

three cents a pound, and of cast-iron guns (finished, tubed, and hooped with steel), fifteen and one-tenth cents a pound.

TABLE SHOWING THE COST OF STEEL AND CAST-IRON GUNS IN EUROPE.

*Steel.*

| | Calibre in inches. | Weight in tons. | Cost per ton. |
|---|---|---|---|
| Whitworth, | 9.75 | 8.02 | $ 824 |
| Krupp, | 13.98 | 51.18 | 1,300 |
| Krupp, | 12. | 35.42 | 1,012 |
| Krupp, | 10.23 | 21.65 | 941 |
| Krupp, | 5.9 | 4.97 | 1,076 |
| Krupp, | 5.9 | 3.44 | 1,074 |
| Krupp, | 5.9 | 3.94 | 1,176 |
| Average, | 9.09 | 18.37 | $1,057, or 53 cents per pound. |

*Cast Iron.*

| | Calibre in inches. | Weight in tons. | Cost per ton. | |
|---|---|---|---|---|
| French, | 9.45 | 15.91 | $349 | Hooped and tubed with steel. |
| Italian, | 9.45 | 14.91 | 305 | |
| Italian, | 9.45 | 17.02 | 307 | |
| Italian, | 12.6 | 37.40 | 259 | |
| Italian, | 12.72 | 99. | 293 | |
| Average, | 10.73 | 36.85 | $302, or 15.1 cents per pound. | |

Table compiled from page 97, Report on Heavy Ordnance and Projectiles, Logan Committee, 1883.

In this country these prices would be forty per centum higher, or about seventy-five cents a pound for finished steel and twenty-one cents for cast-iron guns. Here we have the data to arrive at the cost of aluminum bronze guns as compared to steel. The cost of fabrication would be about the same as with cast iron. Assume that the iron in cast-iron guns costs two cents a pound; deducting this from twenty-one cents we have nineteen cents per pound as the cost of fabrication. Aluminum bronze is on the market at forty cents per pound. Add to that nineteen cents, and we have approximately the cost of the finished aluminum bronze gun as fifty-nine cents a pound.

We have shown that the strength of the bronze is so great that the finished gun need weigh no more, if as much, as a steel gun of like calibre. Hence we arrive at the fact that to-day heavy guns of aluminum bronze can be made at *twenty per cent less cost* to the Government than like guns of steel; and further, *sixty-eight per centum of their cost is represented by capital stored away* in the form of a valuable metal that can *be remelted and used over any number of times* without alteration of its composition.

I close, gentlemen, with the question, Would it not be well for our Government to appropriate ample funds to investigate this promising field, and learn wherein these alloys can be applied in the construction of ordnance and armor?

## DISCUSSION.

The following, contributed by Mr. J. W. Richards in response to the invitation extended him to discuss the foregoing paper, was read to the meeting by Mr. Eugene H. Cowles.

By way of introduction, Mr. Cowles said that it would be of interest to the audience to know something of Mr. Richards. This gentleman was the author, he said, of what might justly be regarded as the best treatise on aluminum that had been published since the appearance of De Ville's profound and yet charming brochure on the subject in 1859. In addition to being a careful and well informed writer on the subject of aluminum, he is also a painstaking scientific investigator of the metal and its alloys.

### A RESUMÉ OF THE HISTORY OF ALUMINIUM.

By Joseph W. Richards, M. A., A. C.*

About 1760, Morveau called the substance obtained by ca
alumina. When, afterwards, alumina was suspected of b
metal, the metal was called aluminium. This, long before it v

In 1807, Davy tried to decompose alumina by the battery, with
decomposed potash, soda, lime, baryta and strontia, but in this
completely. He tried other methods of reduction, but was no suc
Berzelius and Oerstedt were among the many chemists laboring at
and Oerstedt, in 1824, thought he had isolated the metal, but he
be mistaken. In 1827, Wöhler, following a process not very

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Oerstedt's, heated aluminium chloride with metallic potassium, and was successful in isolating aluminium as a grey, lustrous, metallic powder. In 1845, Wöhler improved upon his first process so far as to get small globules, about as large as pins' heads, from which, with consummate skill, he determined pretty accurately the principal properties of aluminium. Thus, while aluminium had been isolated in 1827, for eighteen years its properties "en masse" were unknown, and it was only at the end of twenty-seven years after its discovery that the true properties of the pure metal were established by Deville. The second birth of aluminium, the time at which it stepped from the rank of a chemical curiosity into the number of the useful metals, dates with the labors of Henri St. Claire Deville, in 1854. If Wöhler was the discoverer of aluminium, Deville was the founder of the aluminium industry.

Deville's first success was an accident. He was using Wöhler's method, with some modifications, trying to produce proto salts of aluminium which would correspond with the proto salts of iron; when lo! on finishing one of his experiments, there unexpectedly greeted his sight a metallic globule, a button of pure aluminium, the first time seen pure and "en masse" by human eye. Deville bothered himself no more with the proto salts of aluminium. He recognized all the grand importance of his discovery, and turned all his attention to producing the metal economically. It was a grand problem brought before a master mind. Deville at this time was Professor of Chemistry in the École Normale, Paris. He was practically without the means with which to undertake such an investigation, for his salary was only 3000 fr. ($600), and his estate was small. But he gave a hint to the French Academy of Sciences, and not in vain. He read them a short paper at their séance on Monday, February 4, 1854, simply describing his discovery. The Academy immediately became interested. M. Thenard rose and remarked that he thought it to be the general opinion that such experiments should be actively followed up, and that such experiments being costly, the Academy could hasten the accomplishment of the work by placing at M. Deville's disposal the necessary funds. In a short time after the meeting, Deville was made one of a committee to experiment on producing aluminium, and 2000 fr. were placed at his disposal. With this he labored hard in his laboratory in the École Normale, aided by M. bray, and on August 14th of the same year he read a paper to the Academy methods he had pursued, and showing as the result several bars He also caused a medal of aluminium to be struck, which he the Emperor, Napoleon III. The latter, with that enlightened eristic of the French people, and especially of Napoleon III, orized experiments to be continued at his own expense on a ville, however, about this time accepted, in addition to his or at the École Normale, a lectureship at the Sorbonne, and was not until March of the next year that the experiments at were begun. They were then instituted on a large works at Javel. These experiments lasted three months, accompanied with such success that on June 18th Academy, through M. Dumas, large bars of pure

aluminium. The members and the numerous auditory were loud in their admiration and surprise at the brilliancy and beauty of the metal. Dumas stated that the experiments at Javel had put beyond a doubt the possibility of extracting aluminium on a large scale by practical processes, besides giving to science a reducing agent of the highest importance at a moderate price, namely, sodium. Thus, besides aluminium, many other metals hitherto unknown to industry would be brought into practical use as the result of these experiments. After these remarks of M. Dumas, Deville's paper was read, describing all his processes in detail, and in which he concludes as follows: "After four months of work on a large scale, undertaken without responsibility on my part, and, in consequence, with the tranquillity and repose of mind which are so often wanting to the investigator, without the preoccupation of expense, borne by his majesty the Emperor, the generosity of whom had left me entire liberty of action, encouraged each day by distinguished men of science, I [illegible] to have placed the aluminium industry on a firm basis."

Such was indeed the result of the Emperor's liberality. It is said to have cost him [illegible]. Do you not agree in thinking that the return was out of proportion to the cost? Listen to the testimony of facts as to the result. A quite recent writer says: "In consequence of this Government subsidy the industry of aluminium was able to date its commencement, for at that time the necessary experiments were costly and could not bring commensurate return to the [illegible] experimenter." Another writer says, "France was the first to produce aluminium on a practical scale, and *it is the only country in which [illegible]*." Still another writer says, "*France seems to [illegible] the industry is able to prosper*"—and that was said [illegible].

[illegible] with the [illegible] France, compare this incident taking place [illegible] Mr. [illegible], of Camden, N. J., as early as 1856, became suc[illegible] and made some aluminium, which he [illegible] Franklin [illegible], Philadelphia. He was desirous of experi[illegible], and in this connection the Mining Magazine [illegible] at the expense of the Government; [illegible] arts is a matter of national impor[illegible] the various and innumerable uses to which a new [illegible]. Moreover, it would be quite proper and constitutional [illegible] to appropriate a sum of money to be expended in the improve[illegible] and in testing the value of the metal for [illegible]." The Franklin Institute Journal also remarked: [illegible] enterprises which no manufacturer could afford to [illegible] for the simple reason that he would gain no [illegible] because all would participate alike with him [illegible]. Nothing can give a greater impetus to manu[illegible] in its present state than the introduction and use of new [illegible] the *G[illegible]* take up and pursue this [illegible]."

[illegible] by our Government. As the result, [illegible] has our country made in this branch of science and industry?

It is the nurturing and fostering of industries in their infancy which makes the "effete monarchies" of the Old World still our superiors in so many industrial fields.

Now, to return briefly to Napoleon III., what were his motives? I think, unhesitatingly, they were to foster science and thus enhance the industrial renown of France. And truly, never was renown more cheaply purchased. As a second thought, it is said that the Emperor looked forward to applying such a light metal to the helmets and armor of the French cuirassiers; and, although the first article manufactured of aluminium was, in compliment to the Emperor, a baby-rattle for the infant Prince Imperial, yet the second was a helmet, beautifully gilded and decorated, for the Emperor's cousin, the King of Denmark, which weighed complete only one pound three ounces.

The occasion of this meeting gives rise to quite a coincidence. Napoleon encouraged and really made possible the aluminium industry by looking forward to the industrial credit of the nation, and also to the improvement of the materials of war. To-day's discussion is urged by the promoters of a new industry seeking Government co-operation in bringing into use a metal which all indications and experience unite in commending as promising to be eminently suitable for war purposes. Government co-operation in this case can be looked on more in the light of a judicious investment than merely the general encouragement of science.

As far as aluminium bronze is concerned, its history is contemporary with that of aluminium, and probably has been or will be given at length by others in the meeting. I merely remark that of all the alloys of aluminium, the bronze is deservedly the best known because of its recognized exceptionally valuable qualities. As to its suitability for heavy guns, while knowing the elementary requirements of gun material, I am not familiar enough with the theory and practice of gun building to intrude any remarks of mine on this subject into a discussion in which such recognized authorities are present to take part. However, let me state that the most recent action of the Italian Government, in the artillery line, is the replacement of 4000 steel field-pieces by bronze or gun-metal pieces; the advantage of the latter being that while as safe from bursting and as effective as steel guns of equal weight, they can be cast at much less expense and to greater perfection than the steel guns. Such being the advantages in using ordinary gun bronze, let me ask if it is not in the power of our Government to take a step in advance of the best and most recent modern artillery practice, by undertaking to cast its heavy guns of aluminium bronze?

Mr. Eugene H. Cowles.—*Mr. Chairman and Gentlemen:*—I desire to state here, that in entering this discussion, our idea has not been to seek such Government patronage as has been described by Mr. Richards in his paper. I am glad to state that such aid is not at at all necessary to our success, even were it the habit of this Government to extend its aid to promising inventions; for the Cowles process of electric smelting is far beyond that embryonic state that requires such patronage. Our real motive for entering the discussion may be briefly stated thus: A large plant for the production of aluminum alloys

has been erected at Lockport, New York, and another is in process of construction at Stoke-on-Trent in England; these alloys are being produced in large quantities, and the process is in every way a commercial success; and, finally, with these facts in view, we deemed it proper to extend the market for our alloys wherever possible. We are, consequently, most happy to avail ourselves of this opportunity to discuss the scientific possibilities of aluminum alloys before the Institute, and thus to introduce the matter generally to the naval and military engineers throughout the world.

The following telegram and letter were here read by the Secretary and Treasurer:

PARIS, FRANCE, *Oct.* 27, 1887.

Lieutenant MILES, *Secretary, Naval Institute, Annapolis, Md.*

Received circular letter too late to respond from here, but want to report following fact: A cannon, a mountain artillery gun of aluminium bronze was cast and tested in 1859 by the Committee of Artillery of France. Constant firing, such as would ruin a steel gun, caused only a slight swelling of chamber, and attempts to explode it with heavy charges were also futile. A scientific engineer, School of Liege, Belgium, has responded to your invitation. It cannot reach you until Monday. He reports an experiment with aluminium bronze cast cannon by Colonel Weber, Manager Royal Foundry, Augsburg, Bavaria, 1860, in which the results were highly favorable. It was pronounced by the French Committee and by Weber that the then high cost of aluminium was the only thing prohibitive of its widespread use for guns; it possessing sterling qualities.

BEN. M. PLUME.

PITTSBURGH, *Oct.* 19, 1887.

Lieutenant CHAS. R. MILES, *Secretary, Annapolis, Md.*

*Dear Sir*:—I have your esteemed favor of October 17th. . . . . I am on record as a pronounced enemy, or rather opponent, of the "built-up" guns.

Allow me to say, however, that I think there has been enough said on that subject. The built-up system has been adopted by the Government, and, good or bad, I believe it to be wiser for citizens to sustain our officers, and to try to help them to get appropriations enough to supply us with a respectable armament.

Therefore, if I am not attacked I shall oppose no more, until we have a navy and some heavy ordnance; after that is accomplished, if any person wishes to open up a discussion that can do no harm, it will be entirely proper for us all to go at it again.

For the present I prefer to use my influence in favor of that system which has been approved officially.

I shall not be able to attend your meeting, and you are at liberty to letter as you may see fit. Yours respectfully,

WM.

The discussion was then continued in the following order:

Professor R. H. THURSTON.*—*Mr. Chairman and Gentlemen*:—The paper of Mr. Cowles is to me a very interesting and a very suggestive one. The use of a new metal in the arts, and especially for important purposes, such as the construction of ordnance, is always a matter of singular interest. The introduction of a new system of metallurgical operation in conjunction with the production of a new class of alloys is of such extraordinary importance as to mark an era in industrial history. I regard the introduction of the Cowles methods of manufacture of the aluminium and other alloys as just such an exceptional event, and as one likely to revolutionize, not only the methods of production of this class of alloys, but of many branches of manufactures.

I have watched its development and progress with very great interest from the first, and have been exceedingly pleased with the business like ways and the scientific methods applied in the building up of this new industry. The application of heavy currents of electricity to the melting of refractory substances and to the production of alloys is in itself a commercial and industrial revolution. The derivation of enormously intense and powerful currents by the use of water power, and thus at minimum cost, is a purely commercial revolution of an importance which can hardly yet be realized. The introduction into our markets of metals having the singular and valuable characteristics of aluminium, at such prices that they may have general practical application, is one of those occurrences which only very rarely punctuate our social history. The possibility of rendering available for useful purposes numbers of as yet almost unknown elements and compounds which is thus opened to us, is one of those matters which must be regarded as of extraordinary interest and promise, the outcome of which must be entirely beyond our present view or conception; which may probably be paralleled only by such events as the production of cast iron by Dudley, of wrought iron by Cort, of steel by Huntsman, or the modern "ingot irons" by Bessemer and by Siemens.

I have studied the operation of the Cowles furnaces with all the interest that is compelled by so novel a process and such remarkable products, and have felt that the only question as to its success must be the commercial one, and that must be settled by actual business in the markets of the world. It is gratifying to be assured by the inventors that this is no longer a question, and that the possibility of making such alloys as they have produced, and of being able to put them in the market at fair prices, and at a moderate profit, has resolved itself into a certainty. This being the case, the introduction of the process and of its products would seem to be as well assured as any matter of business can well be. The last is a subject of prime importance where it is proposed to make application of the alloys so made in the construction of ordnance. It would be unwise to venture upon predictions as to the final outcome; but this at least may be said, that we may expect much from so radical an advance in metallurgy, and that we may reasonably hope for almost as great results in the production of alloys as came, in another field, from the invention

* Director of Sibley College, Cornell University, and formerly of the Engineer Corps, United States Navy.

of the great metallurgical processes which now give to the world its various ferrous products.

Considering the application of the newly available alloys to the construction of ordnance, it is first necessary to determine what are the essential qualities of ordnance metal. These I should state in the following order:

1. Tenacity sufficient to meet safely the maximum pressures and stresses due to the heaviest charges and quickest powder to be employed in the gun made of it.

2. Ductility sufficient to resist accidental as well as ordinary strains without danger of fracture and explosion.

3. Hardness sufficient to bear the abrasive action of the shot and its shearing action on the lands of the bore.

4. Elastic "resilience" such that it may not be in the slightest degree deformed by the shock of successive charges.

5. Power to retain the useful and essential qualities which have been above described, at all temperatures, which may be attained in the most rapid firing, even approaching the red heat, if possible.

In the discussion of the paper by Mr. Dorsey, on steel for ordnance, I remarked that I should expect the best metal to prove to be that having the highest ductility consistent with sufficient hardness, which would, in that case, be one of the mild steels, as distinguished from the tool steels; perhaps high in carbon for a steel of that class, but low as compared with the older kinds of steel.* The experience of Mr. Metcalf would indicate, as stated at that time, that it is very possible that as high as 0.80 per cent carbon, corresponding in the unannealed metal to a tenacity of about 100,000 pounds per square inch (Materials of Engineering, Vol. 2; Iron and Steel, §234, pp. 417–421), may be taken as allowable in steel, and as representing the maximum limit for the best; but only, I should say, when exceptional ductility can be at the same time obtained. In other words, a soft tool steel or a hard "open-hearth" product may be taken as representing an ideal material in these respects. The demand should be for a metal having the greatest possible ductility consistent with sufficient hardness and tenacity; the elastic limit being exactly specified at a point in excess of the maximum pressures to be met with, and a minimum figure being given for the elongation to be secured. Steel of 0.80 per cent carbon has an elastic limit, in good samples, of not far from 50,000 pounds per square inch. Its elastic "resilience" is not far from 4000 foot pounds per unit of section and of length. A total extension of 15 per cent, I should say, ought to be expected as a minimum in such steels. Any metal or alloy which is capable of such an extension and of exhibiting such tenacity, in equally large masses, and which at the same time is not too costly in production and application to this purpose, should be considered as a candidate for similar position among the materials to be used in the construction of ordnance.

* This opinion was, in the course of the debate upon that paper, misinterpreted and mean the endorsement of "soft" steel, in the sense in which that word has of late co[illegible] used by those who are familiar only with the "mild" steels as a class. The latter would a steel of one-half per cent carbon a hard steel, while it would be a soft steel when o the intended classification.

The question whether a gun shall be solid or "built up" is, I conceive, usually to be settled by a consideration of the possibility and the practicability of securing in large masses anything approaching the maximum strength of the material as exhibited when used on a small scale. It is not ordinarily possible to secure such tenacity when working in wrought iron, and it is only possible, when using steel, by the adoption of the Whitworth or an equivalent process of compression or solidification. With the cast metals, also, it is not usual to find equal or nearly equal strength in small and in large masses. But could this natural strength, as I would call it, be secured in the solid, as distinguished from the "built-up" gun, there is no difference of opinion as to its desirability to utilize it in one, rather than in a composite, piece. A built up gun may be taken as an attempt to correct one wrong by the introduction of another; to balance a lack of tenacity produced by the ordinary methods of solid gun construction by the use of a complicated, and, to a certain extent, dangerous assemblage of parts, each of which possesses more nearly the desired tenacity.

In choice of material and of method of construction, therefore, I would most certainly look for a strong and tough metal which could be easily and inexpensively worked into large masses of uniform and maximum strength. The best and the only satisfactory illustration of such construction of which I am aware is the Whitworth gun, and that is not fully satisfactory on account of its cost. As regards weight, I should say that, for a gun which is muzzle loading, and usually therefore allowed necessarily to recoil, a certain weight is necessary and desirable to secure proper control of the gun; but I should say that for a breech-loading piece it is desirable to secure all the reduction in weight safely to be obtained, and to so mount the gun wherever practicable that it shall have no recoil—a system proposed by me years ago, and already adopted for casemate guns and for ironclads, in some instances, by Krupp and others. A reduction of weight being made possible by the introduction of a new material, it is a point in favor of that metal. The introduction of aluminium bronze, and other alloys containing that curious metal, seems to promise important advance in the arts, and in none more so than in ordnance construction, if we may take the existing figures as indicative of what may confidently be expected of this alloy when it is attempted to use it on a large scale and in heavy ordnance.

If I may be permitted to judge from what I know and have ascertained from various sources, including the best authorities on metallurgical work, regarding the aluminium alloys, I should say that they are beyond doubt enormously more valuable for ordnance construction than any ordinary bronzes, and unapproached by any alloys, when properly made, except possibly by some of the phosphor bronzes; although I have sometimes found it possible to get extraordinarily high tenacity from the common bronzes by the use of good fluxes and great care in their manufacture, in the manner indicated at the end of Vol. II. of my Materials of Engineering (Non-ferrous Metals and Alloys). As is seen also in the chapter on the "Kalchoids," it is possible to find metals which will alloy in such proportions as to give tenacities approaching those of the ordnance steels and yet with some ductility; but it requires very nice mixture and manipulation to secure such alloys with certainty and safety.

Much has been expected, for many years, from the aluminium bronzes; but their high cost has hitherto prevented their use, and has even prevented any extended investigation of their valuable properties for such everyday purposes as are now proposed by the Messrs. Cowles. But enough has been learned to prove their extraordinary value for many uses. That we shall in some directions be disappointed in our hope of securing remarkable results from them is most likely. It can hardly be supposed that they will prove universally applicable in the arts; but we may certainly, from what we know of them, expect to get good ordnance metals from among these alloys. It was many years ago discovered that some of these alloys were vastly superior to common bronzes in every way, and that they had a strength and a ductility combined that at once promised very extensive useful application. Their exceptional stiffness was one of the first properties noted. The ease of working as compared with some of the more common metals is an important characteristic, and the permanence of the polished surfaces in air, or when exposed to gases, is more than an ornamental attribute. This characteristic has peculiar value in ordnance, and especially should it prove to be thoroughly practicable to make rifled ordnance of it. The ability to withstand the degenerative influences of recasting, discovered by the Messrs. Cowles, is an exceedingly important feature of these alloys; and if it should prove feasible to employ the Dean process of internal hardening and drawing to increase their value, and should this method, which has been found to have such extraordinary value when applied in the construction of common bronze guns, also prove to be equally effective here, the conclusion must be admitted that aluminium bronze is one of the most promising of all the materials which have yet been introduced and proposed for this kind of work. It possesses, in the best mixtures, a tenacity and ductility, an elastic resistance and resilience rivalling the best ordnance steels; its best qualities exhibit sufficient hardness to insure good wearing power, and it can be cast and recast in heavy masses without injury. It is easily worked; is probably capable of profiting by the Dean process, and, if the difference in the coefficient of expansion should not prove to be too great, may probably, when considered necessary, be steel lined. It thus would seem to possess all the desiderata of good ordnance metals.

A gun composed of a metal approaching 100,000 pounds tenacity, and above 60,000 pounds elastic limit, having measurable extension and ductility, hard, unoxidizable, cheap in construction, and durable under wear, would seem to promise well. It certainly would justify the most careful and extended investigation on the part of ordnance officers.

Lieutenant M. E. HALL, U. S. N.—*Mr. Chairman and Gentlemen:*— ,
has so fully and ably set forth the merits and advantages of al
as a gun metal that I merely wish to state that I coincide in the ws
expressed, and to add my experience and observation of the wo
aluminium alloys.

Two years ago my investigations into a suitable metal for a p
led me to inquire into their merits. At that time small quantities o
produced in an experimental furnace, and some of the tin-copper

promised excellent results, the tests showing great strength and ductility. I selected a grade of silicon bronze that in small castings had developed a tensile strength of 74,000 pounds and an elongation of 18 per cent. A flask was cast at the Washington Navy Yard, and a test bar from it showed a tensile strength of but 25,000 pounds, with scarcely any elongation. Upon examining the fracture there were decided evidences of liquation, and upon further investigation I became convinced that this would occur in all large castings of tin bronze, unless chill molds were used to effect rapid cooling.

A representative of the Cowles Company came to Washington to inquire into this unsatisfactory result. He stated that later experiments at Cleveland tended to confirm that made at the Navy Yard. Being satisfied that silicon bronze would not answer my purpose, we cast some test pieces of $A_1$ aluminium bronze, which developed the following properties:

| Dimensions. Length. | Diam. | Weight applied. | Weight per square in. on orig. section | Elastic Limit. | Elongation Per cent | Reduction of area, per cent. |
|---|---|---|---|---|---|---|
| 2.0″ | .500 | 22,485 | 114,514 | . | 0.45 | 0.00 |
| 2.0″ | .501 | 21,650 | 109,823 | 79,894 | 0.05 | 2.39 |

These results were so remarkable that I expressed at the time my belief that the metal would make an excellent gun, if it retained its strength in large castings and under a moderate heat. Further inquiry into the properties of the metal showed that it might not stand the high heat that was an accompaniment of the power I purposed using at that time, and for the time I abandoned its use.

Not being able to obtain a steel flask, after having spent much time and some money in the attempt, I was obliged to change my plans and avoid the great heat required by the former design. During this time I had experimented upon castings of steel, phosphor bronze, and the aluminium alloys, and finding the latter superior in strength as well as ductility, and also far more free from flaws and blow holes, I decided upon the use of aluminium brass, having a strength of 87,000 pounds per square inch. Mr. Cowles and I made various experimental tests, some of which he has narrated. I satisfied myself that even in green sand castings there was no liquation with aluminium bronze or aluminium brass; that they retained their strength in large castings; that aluminium bronze, remelted without the further addition of copper or aluminium, developed the same properties in the second castings, while under the same conditions aluminium brass deteriorated slightly in strength, unless a small percentage of zinc were added. Contrary to expectation, aluminium bronze ($A_1$ grade) was found to be practically as strong when heated to 400° as when at normal temperature. At their works I saw a number of aluminium bronze cylinders 6 feet long and 15 inches in diameter and 2 inches thick, some of which were turned down to ¼ inch in thickness during my stay, and in no case did I see a single flaw after the surface scale was cut under. Of the thirty-three castings made for me, all were good save one, and that gave evidence of having been poured in a damp mold.

It has been the belief in some quarters that the exceptional strength of these alloys was owing to the small castings that test pieces were taken from in the

earlier ones of the metal, but that failure would follow in the attempt to make large castings. My observation leads me to the belief that large castings can be made that will prove fully as satisfactory as those made from any metal, and surpass them all in either strength or ductility.

In the lathe under the tool, A₁ bronze and the higher grades of aluminium brass show properties similar to machinery steel, while the lower grades resemble wrought iron, the turnings coming off in long tight coils. The file makes but little impression on the higher grades of these metals. From this fact it would appear that the fears of abrasion in the bore of a gun when made of other metals than steel, so often expressed by advocates of the built-up gun, are not well founded when applied to these alloys.

One of our eminent authorities (Captain Birnie, U. S. A.), in comparing built-up with solid cast-steel guns, remarks: "We have now reached a stage of gun construction where we are not prepared to accept haphazard affairs. It will be necessary first to establish that the operation of producing initial tension in a steel cast gun can be conducted with certainty, and can be regulated to a proper degree by the manufacturer. When this has been shown, and good sound guns so made, with metal of the requisite physical properties, have been produced, the steel cast gun will have a respectable standing." In the aluminium alloys, possessing enormous strength and great ductility, ranging in the bronzes from 114,000 pounds tensile strength and 5 per cent elongation, to 90,000 pounds and 10 per cent, and to 72,000 pounds and 47 per cent, and in the Hercules metal, varying from 80,000 to 100,000 tensile strength and 20 to 30 per cent elongation, there can be found gun metals whose physical properties would suit the most conservative gunmaker, and whose qualities would satisfy the most arduous conditions of service. With interior cooling and heated molds the initial stress can be regulated, and every condition required for perfect cast guns can be readily fulfilled. Such a gun would give us a distinctive and superior type of ordnance.

In view of the remarkable properties possessed by these metals and the advantages of construction, it would be well to cast two service guns of aluminium alloys and of the types proposed, and to test them thoroughly in competition with built-up guns of the same weight and calibre.

It is to be hoped that the use of these metals for gun construction will be thoroughly prosecuted by our Government, that in future years we may not be called upon to adopt them, as we have done with the Eastman breech block and the Hotchkiss gun, as products of American ingenuity developed by more progressive governments abroad.

Mr. Edward W. Very.*—*Mr. Chairman and Gentlemen*:—I have read fully the advance copy of Mr. Cowles' paper on "Aluminium Bro[illegible] for Guns," and in compliance with your request, venture to expres[illegible]
[illegible]ions with regard to it.
[illegible]far as the comparative adaptability of alumini[illegible]
[illegible]is concerned I can offer no positive opinions, and I [illegible]

* Of the Hotchkiss Ordnance Co., formerly Lieutenant, U. S. Navy.

Cowles should not have favored us with more complete information concerning the technology of this alloy; for, from what little I have been able to ascertain with regard to the possibilities of development of its physical characteristics, I am inclined to believe that in so far as the strength, reliability, and economy of casting are concerned it presents features of promise.

I think that I am right in saying that the gist of Mr. Cowles' remarks may be expressed as follows: that gun construction can be simplified and improved by casting aluminium bronze, using the Rodman process of cooling, and supplementing the work by mandreling the bore. There is nothing whatever irrational in his proposed development, and any good artillery engineer would say that this method has chances of success. None would *prophesy* success, for the reason that there are uncertainties and difficulties to be met with in practice of a very serious nature; so serious, in fact, that they have heretofore proved too great for the success of those who have tried to follow this line of development.

I disagree most radically from the arguments that Mr. Cowles has made in support of his proposed development, for I am certain that not only do they do more harm than good to his case, but that if he attempts to follow out the ideas as expressed in his paper he will certainly come to grief. I shall criticise these arguments severely, and I trust that Mr. Cowles will accept my strictures in good part. He is not an artillery engineer, and is not familiar with the difficulties of practical artillery engineering. I am an artillery engineer, and I beg to call to his attention that I am not a self-styled one through the grace of some invention connected with gunnery, but regularly accredited as such from study of the science, constant practice in all the branches connected with it, and successful practice at that. It is strictly and constantly as an artillery engineer that I earn my bread and butter. I do not mean to imply by this that I am endowed with any grace of infallibility, but simply that in any discussion upon points of artillery engineering I have an advantage over those who have no practical experience in the science, and of those who, on account of a successful mechanical invention, have come to be considered authorities upon the whole subject.

Mr. Cowles makes his principal mistake in failing to distinguish clearly between principle and practice as exemplified in existing gun construction, and I do not hold him in the slightest degree responsible for the error, for exactly this mistake seems to control the majority of the ideas prevalent throughout the United States concerning gun construction. As an instance, he goes at length into the question of the inherent weakness of built-up guns, and calls your attention to the great advantages presented in the Rodman and the Uchatius processes, without bearing in mind sufficiently, if at all, that these processes are simply *practices* by which it is attempted to fulfill economically a single fundamental principle which is as firmly established as the laws of gravity or the sphericity of the earth, and over which physicists have long since ceased to argue.

Whether you produce a gun body by Rodman cooling, by Uchatius mandreling, by wire winding, or by hoop shrinking, you are simply trying to get

as a result a "cylinder of equal resistance," and if any one wants to know what that is they simply have to refer to any text book of Applied Mechanics. A naval cadet in the second class can define it readily enough. Any one of these processes is superior to another only in the measure and the economy with which it fulfills the requirements.

Now, right here I wish time to make a statement of plain self-evident facts. It is the universal practice throughout the world to build up heavy guns by hoop shrinking. Not only do the Government arsenals follow this method, but also the great private establishments, such as Krupp and Armstrong. Let us look farther now, and I will point out the Government of Holland, where for over twenty years the most strenuous exertions have been made to adapt casting and mandreling to large guns. Examine the work of General Rosset, backed by the Treasury of the Italian Government, and carried to the extreme of trying to get a successful seventeen-inch gun body by the Rodman process with cast iron. On the other side, I call attention to the great works of Gruson & Co., in Germany, far and away the best equipped works in the world for casting, and second to them the Seraing Works in Belgium. Neither of these works will have anything to do with the production of cast guns, although gun manufacture lies directly in their line of work. Now, is it not plainly evident that if Germany is forced to hold to Krupp's monopoly, and if Italy, Holland, and Belgium are forced to go abroad for their guns and thus violate one of the first principles of military security—is it not a fair evidence that in actual existing gun making, hoop shrinking is more reliable and economical than casting with the Rodman process? Turn to Austria, where General Uchatius backed by the Austrian Treasury, fairly went crazy in his strenuous efforts to develop the system. Austria's guns are still built by hoop shrinking. Look again, in our country, at the efforts made and still making by Dr. Woodbridge, with the aid of the Government, and at the independent efforts of Sir William Armstrong & Co. with wire winding, and remember that in the latter case wire winding and hoop shrinking are competing in the same shops. I will not cite Longridge in this connection, because he has had to fight the Government in the matter of principle, nor Schultz, who died before he could carry practice far enough. In spite of these strenuous efforts, hoop shrinking is ahead.

Now, mark my demonstration: not one of these abortive [illegible] from an error in principle, nor have any of them caused a [illegible] engineer to disbelieve in their inherent soundness; but, as I state[illegible] these four practices aim at the fulfillment of a single principle, hoop shrinking has so far given the best and *most economical* re[illegible]

There is no use in the lecturer or any one else maki[illegible] the whole world wrong. It is not a case wherein Galileo and the [illegible] be cited, for as a matter of principle the world is on Mr. Co[illegible] wish him success in following up his line of development; but wi[illegible] [illegible] t as Rosset burns his fingers, and such a firm as Gruson [illegible] ke their heads, it behooves the rest of us to "go slow." I [illegible] es from practical experience—and I am fairly f[illegible]

big gun factory in the world through visiting and examining them, and I have had direct dealings and personal interviews with almost every War and Navy Department in the world—that there is not a single one that belittles or denies the practical difficulties or obstructions to successful gun making where shrinking is the method employed—not a single department, either public or private, that would not hail with joy any amelioration of their difficulties. To government arsenals it means greater security and less work; to private establishments it means greater dividends. Surely it cannot be believed that private manufacturers are so fond of the built-up system that they will continue, without a murmur, to make a sheer sacrifice of 40 per cent of the metal in every large tube and jacket forging, or to true up a cylinder of four feet diameter by twenty feet in length to a half a thousandth of an inch for shrinkage, or to sink a hundred thousand dollars in a tempering plant that is of absolutely no value at all commercially outside of gun work. No, no! We must first of all distinctly recognize that, even handicapped with all its difficulties, hoop shrinking has so far given the most satisfactory results, both as to the resulting gun and as to dollars and cents involved. There is no fault at all in the principle involved in casting, but the trouble has been in carrying out the principle.

The lecturer goes into details concerning the bad points of built-up guns. Let us look for a while at the points which he makes. One of his first points in connection with the ideal gun is, that it "must be of one piece in order to act like a great spring." Now, let us look this great spring business square in the face; let us go to any railroad in this broad land and look at the great springs upon which our locomotives and passenger cars are mounted. We shall find them all "wagon springs." True, we shall find also spirals on the bogies, but they are secondary springs; the *great* springs are all "wagon springs," which are certainly not of one piece. Mr. Cowles has made a serious mistake not only in his illustration, but also in his whole conception of the spring as associated with gun-wall resistance. There *is* a connection, but he has missed it.

A little farther along appears an assertion with regard to the distance that a metal will stretch within the limit of elasticity. Why, I ask, go to such pains to lay down a law and illustrate it, on the subject of the "coefficient of elasticity," that every engineer who works in metals, be he an artillery specialist or any other, never fails to take fully into account? This very feature is one of the banes of existence of any artillery engineer who designs a built-up gun, and it will perhaps be a surprise to the lecturer to know that this same coefficient of elasticity will be harder to handle in casting than in shrinking. It is one of those family ghosts that are far better off shut up from public gaze. At least, get acquainted with its tricks before handling it.

I do not wish to be considered captious in my criticisms. If I state that a proposition of Mr. Cowles is either not at all new or is unimportant, I do so not with any idea of stating "what I know about guns," but to convince Mr. Cowles that he proposes to embark in a line of development not a single point of which can either be slurred over or misunderstood. Let me take one of his points and explain my meaning in this respect. Mr. Cowles defines an

ideal gun as one "of minimum weight and simplest construction." Here is a case where his enthusiasm over his alloy and unfamiliarity with the demands have led him into a path which, although of slight importance now at his start, might lead to total disaster. There are undoubtedly circumstances where light weight of gun is an essential, but the great main rule, founded upon the well established principles of dynamics, is to make your gun heavy. I do not mean that you must pile on tons weight, but, if you have a gun and carriage anywhere and under any conditions that together weigh, let us say ten tons, if you could have all the weight in the gun and none at all in the carriage you would touch the ideal. Examine this assertion on the other side and the explanation is self-evident. Suppose that your gun was of the same weight as your projectile, what, pray, would become of your carriage?

Now I assume that since the alloy has a percentage of aluminium, it has a light specific gravity, and Mr. Cowles assumes this to be an advantage. As a matter of fact, I should say that the difference of weight realized in a well built gun would not be of much consideration one way or another; but if Mr. Cowles starts off on the light-gun track, the artillery engineer that has to get up the carriage to hold his gun will kick as viciously as the gun itself against this violation of a mechanical law.

The next point which I shall attack is a very serious one indeed. I quote from the article: "In this brief article I need not refer to the many recorded failures of steel guns, and the known instances of cast-iron guns surpassing steel in endurance and approaching it in destructive power." I would ask if he thinks that the whole artillery world has gone stark staring mad in throwing out cast iron in place of steel—that governments would deliberately pay three times as much for a steel gun when a cast-iron one was better, or that private firms would content themselves with half the profits by working in steel that they could make on cast iron.

If it is not enough that practice should go all one way, I ask if Mr. Cowles will accept the logical deductions from his argument. If there is anything inherent in cast iron that makes it a better metal than steel, then aluminium bronze is inferior to cast iron, since in characteristics it lies nearer steel than cast iron. If, on the other hand, steel as a metal is all right, but it is the process of building that is at fault, then I ask him what he has to say about steel cast guns cooled by the Rodman process such as are about to be manufactured in this country. His argument as made is clearly and fairly against his own metal, but fortunately the argument and the foundation statement are both wrong. If Mr. Cowles proposes to accomplish anything with aluminium bronze, my advice is for him to drop cast iron at once and forever. It is a worse enemy to him than steel.

Let me now take up the laws that are laid down as to the physical re- ments of a gun metal. "The metal around the bore of the gun must have high an elastic limit as attainable; the distance the metal will stretch its elastic limit must be as great as possible; the metal should be as du --sible." If Mr. Cowles will keep these three points strictly t metal, his idea is all right, although I do not think that it is

as to give what is really meant. I wish to point out first some metal indications that are valuable in themselves and certainly should not be lost sight of.

1. What metal can be made to develop the highest known limit of elasticity? Steel.

2. What metal can be made to develop the highest known coefficient of elasticity? Steel.

3. What metal can be made to develop the highest known ductility? Steel. I refer Mr. Cowles to Jean's work on steel manufacture for corroboration of these answers. This work has no special artillery significance, and I believe is considered about the most complete and exact compendium on steel extant.

Now, I do not assert that it follows naturally that because steel may be made to develop the extremes of these qualities, it may also develop all three at once better than anything else, but simply that it is rational to expect that chances would be in favor of reaching the desideratum by some combination of steel. What I should like an explanation of, however, is why, after laying down these laws so positively, he deliberately sets to work to show that cast-iron guns, which have a very minimum of all three qualities, are superior to steel guns. Is it on account of the fact of the casting? Then I cannot see why, in his table quoted from a report on heavy ordnance, he should have taken but four guns, not one of which fills the bill.

1. The Rosset gun, of which I can readily produce the undeniable evidence from Rosset's own pen that the main reliance for developing strength of cylinder was in the steel hoop shrinking.

2. United States cast-iron gun lined with wrought iron. I can produce the written evidence of Sir Edward Palliser that the principle governing this construction was the same as that of the Uchatius mandreling, the cast iron playing a secondary part.

3. Italian cast-iron gun hooped with steel. This gun was built on the French system of construction, which is exactly the same in principle as is followed in all steel built-up guns.

4. Converted cast-iron Rodman rifle. This was a gun converted by shrinking a cast-iron body on a steel tube—a clear built-up gun.

Having cited these cases, Mr. Cowles proceeds to the deduction that they gave greater efficiency because there was a certain percentage in their favor when we come to compare average pressures used with tensile strength of metal. The percentage thus found has no value whatever. What law can be found in the whole range of physics that will permit one metal safely to stand strains beyond the tensile strength of the metal, and that will forbid another metal doing the same thing? Does Mr. Cowles propose to abolish from engineering that item called "factor of safety," or does he assume that however necessary the item may be for railway and bridge building, it may be left out of account in gun building? If the elastic strength of a cast-iron gun is twelve tons, and that of a steel gun is twenty-eight tons, we have at once the percentage of strength. The pressure that people choose to submit them to is another thing.

Mr. Cowles has been told that the Krupp Company will only guarantee their "built-up" steel guns to stand seventy-five charges. He has been entirely

misinformed. Krupp or Armstrong either will guarantee their guns for a thousand or more rounds in so far as strength of gun is concerned. I cannot assert, but I feel quite certain, that there are many steel built-up guns (I use the word, many, advisedly) that have turned three thousand rounds; I know of one gun in this country. In the Hotchkiss shops at Paris there is a gun (a 3.2 inch army gun), light, it is true, but it is a steel built-up gun, and the maximum chamber pressures used in firing average about 15 tons per square inch. That gun has stood about 2800 rounds, and is in use constantly in testing ammunition. I frequently have to stand up behind that gun and fire it from the shoulder, and I hope to get many shots from it yet. I am confident that it will not be condemned until the rifling is all worn out of it.

Mr. Cowles gives an estimate of cost of gun building, in which he starts with an assertion of the cost of steel guns in Europe. I suppose that he has taken the figures from *selling* prices in Europe. Certainly he does not mean to tell us that he knows what it costs Whitworth or Krupp to build a gun; that is a trade secret. He compares this price with the cost of French and Italian cast-iron guns. These being government prices, are *cost* prices. Now, on top of a selling price he adds 40 per cent for American cost prices, and then makes deductions for the price of aluminium bronze. Mr. Cowles, I am certain, is sincere in his estimate, but I can give him a few points, I think.

In the first place, he can find out exactly how much it costs to build a steel heavy gun in this country by asking at the Naval Bureau of Ordnance. I have not asked, but if the average price is as high as 45 cents per pound I am very much mistaken. As for the 40 per cent premium on American labor, that is absurd. Guns can be built, are being built, and I am in charge of the building, that will cost nothing near that amount more than they would cost in Europe, and I pay very high prices comparatively for material.

I close with an answer to Mr. Cowles' last question: "Would it not be well for our Government to appropriate ample funds to investigate this promising field, and learn wherein these alloys can be applied in the construction of ordnance and armor?"

I answer most emphatically, no—not while an American has the to stand up on his own feet and do his own work. What! are we artillery people to turn beggars and go chasing after Co money to work out our ideas? Is this the way that Edison does r locomotives, our reapers, our sewing machines, our Winchester r reputation as inventors come from the Congressional nursing? Let Congress say whether it wants a defense for the country or the business of Congress. Let the military and naval depar are needed for defenses. That is their business. Let squarely, and unaided, as I demand that others shall, to sup the is demanded by those military and naval departments. Th It is a business conducted on the broad free American plan. I do mity to Mr. Cowles' system. I do say, however, th him must in like manner be given to Wiard, to Hask to r lding, to Berdan, to Zalinski, to any one and every one

scheme for the defense of the country. Give to all or give to none. I say give to none. Mr. Cowles may receive government aid in development, and if he does, I predict for him the same measure of success for his system that has followed like donations. Nothing so quickly generates dry rot in the brains that work. I know what it is, for I have worked in the service with my salary ensured, and I am working now out of the service with my income dependent on my work. No one ever loved the service more than I did, or felt more aptitude for a sailor's profession. I have worked harder and longer since I left than I did while there, and never for a moment have I regretted leaving the Navy; for I never knew there what I could accomplish if I was pushed to it. One of these days, when I get too old to do anything, I may want to be led to the trough to feed, but not yet. I prefer to stick to artillery engineering, and when casting, or wire winding, or mandreling get ahead of hoop shrinking, I will be there with it. I wish Mr. Cowles all success, and, as I said at the start, there is nothing irrational in his proposed development; but before he starts I beg him to make up his mind to go slow, go sure, and above all, go it alone. If he does otherwise, he will not only fail, but will drop to that unenviable condition so well known about the halls of Congress, of "a man with a grievance."

Lieutenant ALBERT GLEAVES.*—*Mr. Chairman and Gentlemen:*—The arguments that the lecturer uses against steel built-up guns, such as the impossibility of learning the exact elasticity of great masses of metal, variations in their elasticity, variations in their contraction during cooling, apply with equal force to cast guns of heavy calibres, whether of steel or aluminium bronze.

In referring to the present methods of gun construction on the principles of initial tension and varying elasticity, it is stated that "to accomplish this satisfactorily by building up a gun is generally conceded to be impossible," and that it calls for such nicety of work, "practical men consider it impossible." The magnificent steel guns that are yearly turned out at Essen, Woolwich, Abouchoff, and by the firms in France, are the most conclusive answer possible to these statements, and the list of practical men and distinguished artillerists who build and advocate them includes names too well known to require mention. But it will not be necessary for the lecturer to leave the United States in order to see a satisfactory built-up all-steel gun, for within a short distance of this hall are built-up steel guns that have been proved to be satisfactory in every respect. Mr. Longridge, the eminent advocate of wire-wound guns, opposes built-up steel guns, but the substitute he proposes will, by his own calculations, be inferior to the service gun; for the 5 ton wire-wound gun recently ordered on his design is expected to have, with a 100-pound shot, an initial velocity of only 1870 feet, while the corresponding steel gun with the same weight of projectile gives 2000 feet. Advocates of the steel gun do not claim that it is the ideal gun, "in which the initial tensions of the metal vary from the centre outwards, corresponding exactly with the variations of the strain thrown upon the different parts at the moment of explosion," but they do claim

* On duty at the Naval Ordnance Proving Ground, Annapolis, Md.

that this is more nearly accomplished, and with fewer accompanying evils, than by any other method of fabrication.

The lecturer suggests two methods for the fabrication of aluminium bronze guns, namely, first, upon Rodman principles, and second, upon those of Uchatius. In regard to the first, an Italian writer in 1882 said, in speaking of the splendid results obtained by the Rosset guns (cast on Rodman's plan and hooped with steel), "in heavier guns we cannot be certain of obtaining homogeneity throughout thickness of the metal," and "can we hope with this system not to fall behind? Will it not be more prudent to abandon entirely the use of iron, and seek in steel a strength that iron cannot give, and which the present condition of artillery demands?"

Again, the Austrian artillery, which is quoted as having used exclusively since 1873 the Uchatius method, is composed, according to Brassey (January, 1886), of ten types of Krupp guns, two of Armstrong, and three of Uchatius, the calibres of the latter being 5''.87, 3''.43, and 2''.87. It has been stated in England that attempts to fabricate on this principle the large tubes required for heavy natures have been unsuccessful; moreover, the method was abandoned in Austria in 1881 on the death of General Uchatius, and the Krupp steel gun adopted.

The difficulties in casting guns increase rapidly with the calibre, and as yet have not been overcome. The only proof that it is possible to cast a successful high-power gun is the actual accomplishment of the fact—all else is theory.

Neither the powder pressures alone nor the tensile strength of the metal in guns is a criterion of their efficiency. As Major Mackinlay remarks, in his excellent Text-book on Gunnery, the best measure of the efficiency of a gun is the amount of work producible with safety per ton weight of gun, and on this basis, with the data compiled by the lecturer, let us compare the much abused steel gun with the cast-iron gun.

STEEL GUNS.

| | Cal. inches. | WV. tons. | Projectile. pounds. | I. V. feet. | Work per ton weight of gun. |
|---|---|---|---|---|---|
| (*a*) | 15.75 | 71 | 1711 | 1702 | 484.4 |
| | 13.97 | 51 | 1155 | 1642 | 423.5 |
| | 12. | 36 | 664 | 1517 | 294.7 |
| (*b*) | 15.75 | 71 | 1762 | 1695 | 495. |

CAST-IRON GUNS.

| | Cal. inches. | WV. tons. | Projectile. pounds. | I. V. feet. | Work per ton weight of gun. |
|---|---|---|---|---|---|
| (*a'*) | 18. | 87 | 2200 | 1378 | 333.5 |
| | 12.6 | 38 | 770 | 1492 | 313.2 |
| | 12.25 | 40 | 700 | 1485 | 268. |
| | 17.72 | 100 | 2204 | 1512 | 349.9 |
| | 11. | 24.3 | 543 | 1352 | 283.3 |

From this we see that the steel gun (*a*) of 71 tons, weighing 16 tons less [illegible] the cast-iron gun (*a'*), does 151 feet tons per weight of gun more, which repsents an increase of 45 per cent in efficiency, and the steel gun (*b*) manner 41 per cent more efficient than the 100-ton cast-iron gun which w

29 tons more. In other words, with a strength of metal three times as great we have increase in efficiency of 41 per cent to 45 per cent, instead of 25 per cent when the guns are improperly compared as to their tensile strength and powder pressures alone. Even if these cast-iron guns did the same amount of work as the steel guns with which they are compared, the great difference in weight would be a most important factor in favor of the steel guns for naval artillery. Moreover, in speaking of the pressures in cast-iron guns, the lecturer does not follow out his own distinction between cast-iron guns tubed or banded, and homogeneous guns. As a matter of fact, the pressure in homogeneous cast-iron guns varies from about 8 tons in the IX-inch S. B. to 11.3 in the XV-inch.

Let us now consider the relative endurance of cast and built-up guns. The life of our old cast-iron guns is estimated to be 1000 rounds, but cast guns have been fired as many as 3000 rounds. The endurance of steel guns is perhaps not so great, but, as has been shown, steel guns do much more work and are therefore better. Colonel Maitland mentions a 6-inch gun that was fired 1800 times, and an 8-inch 12-ton gun that was fired 67 times "between breakfast and lunch." An 11-inch B. L. which was found to be unserviceable from erosion after firing 95 rounds, was lined, and up to February, 1887, had fired 239 rounds and still remained serviceable. In 1886 trials were made at Gâvre to determine the life of steel guns, with the following results, which are taken from the recent N. I. office publications:

2".56 steel B. L. R. This gun was fired in all 2081 times, and although the erosions were so great that the lands were almost entirely gone, the resistance or strength of the piece was adjudged to be as good as when new.

3".54 steel B. L. R. Fired 900 times.

3".9 steel B. L. R. Fired 1295 times; owing to great erosions at 1115th round the life of this piece was set at 1000.

5".5 steel B. L. R. Fired 424 times and the life of the gun placed at 400.

6".3 steel B. L. R. Fired 595 times, 539 rounds being with service charges. It was not until after the 338th round that any change could be observed in the bore.

"Guns of this character can only be regarded as unfit for service in war after they have lost this accuracy, or when they are so much weakened that a rupture of the piece may occur." It is to be noted "that the power to resist rupture was never impaired beyond a point of safety, and that relining the bore would have made the guns almost equal to new ones."

The guarantee of the Krupp gun to be only 75 rounds, standing alone as it does in the lecture, is apt to be misleading. It probably means that the gun is guaranteed to stand 75 rounds before it becomes necessary to reline the tube.

That aluminium bronze is estimated to cost 16 cents per pound less than steel is not a particularly weighty argument in its favor, for that gun is the cheapest *always* which is the best, regardless of its intrinsic value.

No doubt it would add much to the appearance of a man-of-war to be armed with guns that rust does not corrupt and that have the lustre of gold, but so would purple sails and silver masts. However, the great question is one of efficiency; and if guns cast of aluminium bronze are better than steel guns,

by all means let us have them, but as at present these guns exist only on paper, it is simply a question of theory against practice. If the lecturer will produce a gun cast of aluminium bronze which will stand the prescribed test and give better results than built-up steel guns, then ordnance officers will be as eager to defend it as they now are to uphold the steel guns which have so far surpassed all others.

Ensign J. H. GLENNON.*—*Mr. Chairman and Gentlemen*:—Looking over this paper in some detail, we come first to the physical properties that a metal should possess in order to make a good gun metal. The lecturer states first that the metal around the bore should have as high an elastic limit as is attainable. This, of course, is true so long as we use a metal that is safe in other particulars. It is the reason for using medium steel in préference to low steel, wrought or cast iron, or aluminium bronze, if we consider what is really already attained with that metal as shown by the paper before the Institute. Secondly, he says the distance the metal should stretch within the elastic limit should be as great as possible. The reason for this is not evident, nor does the illustration given by the lecturer really prove anything. There is a limit to the allowable stretch. A metal that would extend like India-rubber, for example, would not do at all. Nearly all the work of the powder would be wasted in stretching the gun; and in two guns, the elastic extension of one being twice that of the other for the same pressure, there would be just *twice* the work, useless work, expended on the first that there would be on the second. This work would, of course, lessen that done on the projectile. In any gun, however, this quantity would be small; there would not be enough extension to lessen the pressure materially, and we would find that the maximum pressures two guns could stand, supposing their elastic strengths equal, would be precisely the same, and entirely independent of the elastic extension.

The lecturer says, thirdly, the metal of the gun should be as duc s
sible. There is no one thing more written about in discussions
ductility. The lecturer believes in making a gun a spring. at
ductility in a spring, as a spring? *No* ductility in a gun metal w
sirable; but excessive ductility is not needed. If a higher
attained by stretching a metal somewhat, provided that we do not
weaken it to resist compression, ductility can be brought into y.
permanently stretch the metal, and get rid thereby of some of
But after a gun is down to its finished dimensions, it is a bad
have such a low elastic strength as will bring its ductility into p
the gun, as it will if properly constructed, will extend during ar
wards return to its original dimensions, the bore which is cylindri
will remain so. If not, parts unequally strained will have a
shapes. A gun is unequally strained in its different parts. The b
firing, if ductility is brought into play, will therefore necessarily be
This in itself will cause irregular strains in future firings, and
irregularities, which must be removed in some way or else the

* Instructor in Ordnance and Gunnery, U. S. Naval Academy.

if removed, we will have a weaker gun than we had originally, and can go ahead and repeat the process until we are sure we have no reserve ductility to count upon, when it would be a wise precaution to stop firing altogether. A gun may be so built, as is the Navy 8-inch M. L. R., that it is really not finished until after some of the ductility of the inner tube is brought into play; in the particular case cited it is *necessary*, in order to set the tube firmly in its cast-iron casing. Of what further use is the great reserve ductility of the wrought iron, which cannot be brought into play at all except by bursting the outer cast-iron body? A little further on, the lecturer speaks of the value of cast iron as a cannon metal. Whatever other properties it may have, it certainly does not possess much ductility. On the other hand, wrought iron does possess great ductility. In guns, however, it has been *fully* tried; and found wanting, if we can judge anything from the action of Great Britain in this regard.

With respect to the fourth point, hardness, steel with a high elastic limit *is* hard, and naturally, with steel guns, we hear little talk about this particular property.

To realize the principle of initial tensions *exactly* is the mechanical impossibility. That it is realized *satisfactorily* is proved by the fact that all gunmakers, private firms whose pockets are affected by failures in their guns, adhere to it. It is impossible to realize the full tensile strength of the metal in the form of pressure without permanently deforming the gun, where we use any metal of which the tensile is double the elastic strength, no matter how the gun is put together; unless the elastic limit for compression is very much greater than that for extension. The lecturer says nothing about the elastic limit for compression of aluminium bronze in its original form, not to speak of what it is after mandreling. (By mandreling the gun he is bound to stretch the metal more than he compresses it, unless the outside is held in some way.)

The $\frac{1}{2000}$-inch tension mentioned by the lecturer is tension per inch. In a ring 17 inches in diameter this would be .027-inch extension for the circumference, and would be very quickly noticed.

In steel built-up guns the shrinkages can be calculated for the minimum value allowed of the elastic strength of metal. The modulus of elasticity for different steels being practically constant, the gun will certainly be as strong as it is calculated to be.

It would certainly be hard to say what would be the effect of vibration in a built-up gun, or in any gun, when we remember that the blow is not delivered at a point, but along the whole bore successively. Nor does the fact of vibration seem to have much bearing on built-up guns and gun-bursting, as all the recent guns that have failed have done so at points where the guns were not built up.

The lecturer apparently thinks that cast-iron guns with steel or wrought iron tubes are not built up. They are, however, just as pure examples of the built-up gun as if both parts were steel and one shrunk on the other; the difference is in the way of the building. In the one, the outer tube jacket or hoop is shrunk on; in the other, the inner tube is forced out.

A comparison in the efficiency of guns can easily be instituted from the guns at present in the naval service. Take the two 8-inch guns, the one all

steel, the other cast-iron body with wrought-iron tube. The first has a muzzle velocity of 2000 feet, the latter 1450 (however, not realized in practice); the projectile of the former weighs 250 pounds, of the latter 180 pounds; penetration of the former in wrought iron at least twice that of the latter; the extreme range at least double; the accuracy in firing in a still greater ratio, and the muzzle energies 25 to 10.

General Uchatius was modest, and started with a tube of 43,000 pounds tensile strength, 6000 pounds elastic strength, and by mandreling raised the elastic strength of metal next the bore to 15,000 pounds, or about one-third the original tensile strength of the metal. The lecturer, by mandreling, proposes to raise the elastic strength of the metal next the bore to the full original tensile strength of aluminium bronze. This is mere speculation. Nobody would accept it without experimental proof. Mandreling, by the way, is practised on steel tubes for guns. Why not start with steel of 60,000 pounds elastic strength at once, and raise it by a similar process (on paper) to 120,000 pounds? Or, to take a metal with very similar properties, why not use mild steel of 70,000 pounds tensile strength and 30,000 pounds elastic strength, with a percentage of ductility of 30 per cent, and raise its elastic limit? The elastic strength of the steel is the greater, and the other qualities are the same in the two metals. What is there in the process that would apply to the aluminium bronze and not to the steel?

One point more: bronze in guns has always been more or less affected by the heat of firing. The metals of the alloy show a tendency to separate, leaving the strength of the gun that due to the copper. The lecturer does not say much on this point. At each fire, the bore has to stand a temperature somewhere between 3000° and 4000° F. After a few rounds fired quickly, the outside would be too hot for the hand. The only experiment quoted in respect to the effect of heat on aluminium bronze is one in which the alloy, after standing over 100,000 pounds stress when cool, broke at 86,000 pounds when heated, having stood over 100,000 pounds when heated once before. Might not the developed weakness have been due to reheating or over-heating, though the temperature was only 400° F.?

In conclusion, if a steel gun shows wear and tear in practice, we have always the option of falling back on the low charges, pressures, and velocities of cast or wrought-iron or bronze guns. The original cost of the gun being but a small fraction of the cost of the ship, and this in turn nothing in comparison with loss of prestige, or damage that might be incurred except for the ship, why should we not have the very best guns, granting that they do cost more?

We have very good guns now, as good for like calibres as any other nation. We want even better, and there are excellent chances for them in the very line now being pursued—guns made of steel, and of higher steel, even, than is now being used.

Mr. Birdsill Holly*:—In a gun, the one physical property, above that the metal of its walls must possess is a high elastic limit. T

* Hydraulic and Steam Engineer, Lockport, N. Y.

Mr. Cowles says, this determines the pressure a gun will stand without distortion. Cast iron, wrought iron, the mild steel of commerce, and gun bronze have not this property; hence it would seem that the competition of the future must be between finer qualities of steel on the one hand, and some new and strong alloy on the other. The aluminium bronzes, having such high elastic limits, in addition to their other valuable qualities, appear to offer metals that will overcome the objections that have been raised against steel.

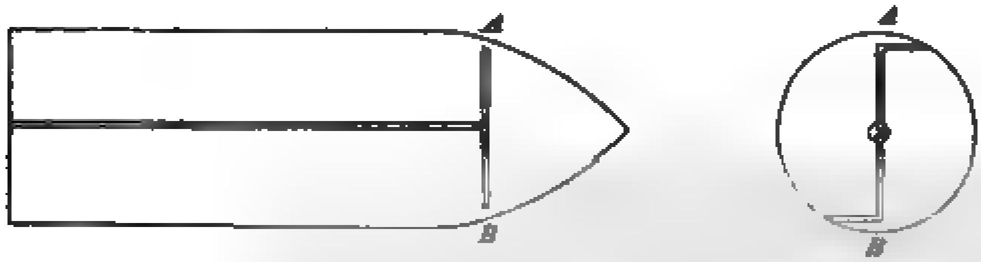
In order to utilize the total strength of the walls of a gun, these walls should, theoretically, consist of an infinite number of laminæ, put together with a gradual series of positive and negative compressions, of decreasing value from interior to exterior, so that under pressure of discharge the interior compressions will be converted into tensions, until one uniform strain is applied throughout. Notwithstanding this, all the work of making a gun has to be done by men, and men are sometimes careless. If they bore a part too large or too small, they will endeavor to have those parts go together before they are caught at it. I do not wish to say that the inspecting officer would be careless, but his opportunities are great.* If the tensions that are established in building up a gun are permanent, how is it that in the old Dahlgren guns the internal strains formed by external cooling during casting disappeared, through the effect of expansion and contraction with age and variations in temperature? If a gun is burst it may be broken into twenty parts; and making it in a dozen parts, to start with, is not mechanical. In such guns the continual dragging of one part on another, due to a difference of expansion, is not desirable. No two pieces of iron or steel expand equally. It would be best to abolish the steel tube in the solid guns. In order to accomplish this, radical improvements must be made in rifling. The accelerated twist, with studs to follow the groove, is not right, as only one stud can act in the groove at a time, thus concentrating the friction to too great a degree. With a uniform twist, and expanding soft metal on the projectile, at the moment of explosion this metal is being pressed forward with a pressure of from fifteen to twenty thousand pounds to the square inch, yet that part which is farthest forward is being held back by its friction against the walls. Under these conditions the soft metal flows like water and transmits this abnormal pressure to the wall of the gun, causing a great and uncalled for friction, loss of energy, and abrasion.

If grooves must be used to give the rotation, the true mechanical method would be to have many of them. The friction is dependent upon the pressure, not upon the extent of surface. Too small an extent of surface will increase friction due to increased abrasion. The bore of the gun should be milled, and its cross section should resemble a fine-toothed gear wheel with the corners slightly rounded. The same miller should be used on the shot. Iron or steel working against hardened bronze would create less friction than if working against steel. In order to prevent the escape of gas through the windage, I would, with his consent, offer a method that was suggested by Lieutenant

* Alexander Holley's "Ordnance and Armor," p. 322. Cook's "Text-book on Naval Ordnance and Gunnery," p. 121.

M. E. Hall, U. S. N., which embodies the application of a principle that I patented about the year 1854. It is this: if a fluid be flowing under pressure through contracted orifices from one cavity to another, if there be but two cavities the pressure is reduced one-half in the second cavity, and if there be one hundred cavities it is reduced to one one-hundredth in the last cavity. Thus by cutting a large number of small grooves around an engine or pump piston I was enabled to prevent the passage of steam or water between it and the wall of the cylinder, although there would be a free opening from one side to the other. This principle is blind, and it once required much exertion on my part to prove it to engineers. It is now, however, very widely used in steam and hydraulic engineering. If our projectile, now, has grooves turned around it one-fourth of an inch apart, one-fourth of an inch wide and one-tenth of an inch deep, and in the bottom of its rifled grooves a series of shallow holes one-quarter of an inch apart be bored, no appreciable amount of gas can flow between it and the walls of the gun; this is assuming we have an ordinary loose fit between the projectile and gun. The same principle could be applied to prevent the escape of the gas through the vent. This grooving might increase the friction of the air during the flight of the projectile. This is ordinarily small, and experiment would determine whether the increase would prove a serious objection. By preventing the escape of gas through the windage, erosion forward of and at the seat of the projectile would be eliminated, the enlargement of the powder chamber would be lessened, as is always the case when a wad or sabot is not used. There would be no appreciable tendency toward the formation of the "indentation and enlargements," as they are dependent upon the unequal pressure of the gas, during its escape, upon the projectile, and with these defects absent greater accuracy would be obtained. It would seem as though there would still be a slightly greater pressure above the projectile than below and cause a downward pressure. In designing and working the Silsby rotary fire pump I learned that practically such is not the case, and that the grooves fully overcome this inequality. Further, the friction between a projectile and the walls of a gun is inappreciable, as far as the weight of the projectile is concerned, but comes either from the pressure of the powder gases being greater against one side of the projectile than the other, and this pressure being transmitted to the wall, or, in the case of an expanding projectile, the powder pressure being transmitted to the walls through the soft metal. In either of these cases the pressure is tremendous, and so are the friction, the wear, and the loss of energy, and the lessening of the life of the gun. The grooves would almost abolish these evils, and allow the ball to slide out with the same freedom that exists when it is driven home.

We still have a *rifled* gun which, to my mind, is not mechani
the gun at all? A small hole, passing longitudinally thro an elo
projectile from its base to a point where its diameter has bee
then branching at right angles to the axis and passing nearly to
and again each branch turning at right angles, but in opposite
plane formed by the two former lines, and passing out of the proj
create vents for the gas which would give to the ball a r




The size of the escaping orifice would determine the rapidity of rotation. The principle is the same as is used in the old Scotch motor, in which water is taken in at the centre, and ejected through pipes at tangency to a circle of revolution. The efficiency of this is as high as seventy-five per centum. The same would be true if our projectile is made into a rotary engine. It is an easy problem, knowing the diameter and weight of the projectile, and the average pressure of the powder gases for a given time, to determine the size of the small discharge pipes which should give the desired revolution. By this means the loss of energy due to obtaining the revolving motion second-handed, from the forward motion of the shot, would be saved, and the wearing of the rifling grooves would be obviated. There would be no weakening of the gun due to the grooves, and *smoothbore guns could be used as rifles.*

I make these suggestions to point out the possibility of overcoming difficulties that may arise in utilizing the best aluminium alloy as a gun metal. The object to be achieved is great. In order to find the best metal for guns, at the present time, it is worth while for our Government to exert every effort. There are many unknown alloys of aluminium that should be investigated. Through my residence being in Lockport I am familiar with some of the capabilities of the electric furnace and the wonderful properties of the aluminium alloys. The bronzes shrink more than cast iron. This is the case with all strong metals, and is easily overcome in casting. The absence of blow holes and the lower melting temperatures give to these alloys a great advantage over steel. The method of making alloys is such that stimulation such as Government patronage would give would greatly lessen their present reduced cost and enable them to enter into very general use. Were I to make a gun I would adopt the Parrott gun as a model, and make it with one reinforce, using such alloys of aluminium as would enable me to apply the principle of *varying elasticity.* The reinforce should be driven or screwed on by hydraulic pressure. The parts could in this case be cast with uniform dimensions. The Rodman method of casting would be used, keeping the outside of the mold heated.

The range of properties attainable in aluminium bronze is in its favor. While it was in the furnace I have seen it "doctored" and tested and almost any desired property obtained. It is uniform in its composition, and does not separate into a number of different alloys as does the tin bronze. We *know* that bronze guns are used and that they do not burst. I have long been of the opinion that if we could double the strength and elasticity of bronze, we would have a metal superior to steel for guns.

[illegible] — [illegible] *and Gentlemen* — The able paper [illegible] [illegible] properties of aluminium bronze for heavy [illegible] by the Institute to discuss, presents many [illegible] of this alloy as a structural material.

[illegible] Mechanical Engineers in New [illegible] to the casting of strong metals [illegible] of the opinions there expressed are [illegible] same, as the ideas then advanced [illegible] bear so directly upon the practi- [illegible] fabrication of guns.

[illegible] form castings from them, pre- [illegible] in the manufacture of ordnance [illegible] certain peculiarities inherent in most strong [illegible] *and, close* castings a much [illegible] cast iron. These evils are [illegible] *in of gas.* This latter [illegible] into the mold during pouring, or [illegible] solidification. In casting steel the [illegible] most serious difficulty.

[illegible] of aluminium bronze are, in some [illegible] encountered in casting steel. Much [illegible] ordinary methods, but in peculiarly [illegible] means and extra display of skill and [illegible] metals there appears to be a "red short- [illegible] become solidified at which they [illegible] very little resistance to their contraction, and [illegible] detected by the eye, but becomes [illegible] upon the casting. To overcome this [illegible] freedom in contraction, different [illegible] and metals. Provision must [illegible] parts forming the interior por- [illegible] flanges, etc., oppose to freedom [illegible] cores must be "rotten" and of a [illegible] using rosin in coarse sand, and [illegible] large vent-holes as possible, and by [illegible] irons. The rosin causes the core, [illegible] to the pressure of the contracting [illegible] are able to surmount almost any [illegible] from the evils of contraction, so far [illegible], and similar provisions can be made in [illegible] large cylinders, such as a gun cast by [illegible] wound around the barrel or cooling [illegible]

[illegible] of the [illegible] of L. D. W[illegible]'s Foundry Co., Cleve-

Like contraction, shrinkage is found seriously to interfere with the obtaining of perfect castings from all metals. In making steel castings much labor has to be expended in providing risers sufficient to feed them solid or prevent "draw holes" from being formed, and in casting aluminium bronze a similar necessity is found. The only way to insure against the evils of shrinkage in this metal, with work requiring "risers" or "feeding heads," *is to have them larger than the body or part of the casting which they are intended to "feed."* The "*feeder*" being the larger body, it will of course remain fluid longer than the casting, and, as in cast iron, that part which solidifies first will draw from the nearest uppermost fluid body, and thus leave holes in the part which remains longest fluid. This part is cut off in the finished casting. A method which I originated and found to work well in assisting to avoid shrinkage in ordinary castings of aluminium bronze was to "gate" a mold so that it could be *filled or poured as quickly as possible, and to have the metal as dull as it will flow and yet secure a fully run casting.* I have made in this way very disproportionate castings without "feeders" on the heavier parts, and upon which "draw" or shrinkage holes would surely have appeared had the metal been poured "hot."

The principle employed in making large castings from this bronze is similar to that used in casting steel, and, as is well known, consists in pouring through a spout controlled by a valve, which allows the metal to flow from the bottom of a ladle instead of the top, or lip, as is practised in pouring cast iron. The exact plan which I used for castings weighing over fifty pounds was to make a "pouring basin" sufficiently large to contain all the metal necessary to fill the mold, the "feeding heads" and "gates," and leave a surplus for a "flow off." No metal was allowed to enter the mold until all was in the "pouring basin." The entrance to the "gate" was stopped by means of an iron plug, and the moment all was ready it would be pulled, and the metal would almost fill the mold, so large would its gates be made. Instead of a "pouring basin," a "secondary pot" or ladle can often be well used. By such plans it will be seen that there was *no danger* of any "scum" or oxide entering the mold, which would seriously mar the appearance and lessen the strength of a casting. Again, the pouring gate is air tight, hence the falling metal cannot, as by the ordinary method, entangle within itself air bubbles, which would be carried into the casting and create "blow holes" in cases where the metal chills quickly. I explained this a year ago at the meeting of the American Society of Mechanical Engineers. This theory has since been beautifully illustrated by W. F. Durfee, M. E., in his paper entitled "Iron and Steel and the Mitis Process," presented to this honorable society, May 11, 1887.

From blow holes, castings of aluminium bronze are free. Should any exist, it is the fault of the molder or his mold. It contains no gas to liberate at the moment of solidifying, as is the case with most steel. The Otis Steel Company, of Cleveland, Ohio, can and do perfectly overcome this difficulty in steel castings. Sand molds for heavy work *must be well "vented"* and of "dry sand." For "blacking the molds," use the same mixture as is found to work well with cast iron. The metals run well in our ordinary molding sands, also iron chills or molds, and "peel" perfectly. The bronze having such a low

"*pouring*" temperature, presents many advantages to the founder in molding and procuring massive castings. This, in connection with its perfect homogeneousness, gives properties very essential in approaching the ideal of perfect gun metal. I have made many perfect castings from these new alloys, and hence my familiarity with their characteristics.

The Rodman method of casting has done its work so well with cast iron, that, considering the features I have mentioned above in connection with the physical properties of the aluminium alloys, good results should be obtained by its application in casting these metals.

The information which is being obtained by your discussions on the fabrication of heavy guns is very valuable and instructive to the metallurgical world, and will ere long, with the wise discretion of our officials, once more assist our government to come to the front in heavy ordnance.

Professor CHAS. F. MABERY.*—*Mr. Chairman and Gentlemen*:—In answer to your invitation to express opinions concerning the paper of Alfred H. Cowles on aluminium bronze for navy guns, it may be of interest to call attention to the peculiar property aluminium bronze has of resisting the action of ordinary corrosive agents. The durability of a gun evidently depends to a certain extent upon the capability of the metal of which it is constructed to withstand the corrosive action of the products of explosion; and of two metals with equal qualifications in other respects, the one that possessed this property in a high degree would have a decided advantage over the other. It is well known that no common alloy can compare in this respect with aluminium bronze. The peculiar nature of this alloy, which approaches that of a chemical compound, serves to protect the copper from oxidation, and the resistance of aluminium to the action of sulphur seems also to diminish the readiness of copper to unite with this element. Carbonic dioxide and nitrogen, the chief products of the explosion of gunpowder, would not affect aluminium bronze, and the same would doubtless hold true concerning the gases formed in smaller quantities—carbonic oxide, hydrogen, hydric sulphide, sulphur, and oxygen. Neither would the principal solid products of an explosion—potassic sulphate and potassic carbonate—corrode the metal; and the sulphur compounds—potassic sulphide, potassic hyposulphite, potassic sulphocyanate, etc.—would probably have little effect upon it.

Another distinctive characteristic of aluminium bronze is its freedom from liquation. The aluminium does not melt before the copper, and, except a very slight loss from oxidation, no change in the proportions of the alloy is observed after a series of meltings. In this respect the metal is superior to the tin bronzes, in which, as is well known, the tin is liable to melt away from the copper, thereby changing very materially the nature of the bronze. Aluminium bronze would doubtless be free from this defect, since no change in the proportions of its constituents would result by liquation at any temperatures below the melting point of the alloy.

*Case School of Applied Science, Cleveland, Ohio.

It has been suggested that the superior strength of aluminium bronze manufactured in the electrical furnace over products obtained by melting together copper and aluminium, may be due to a more complete incorporation of the constituent metals during the process of reduction. Whether this is true, or whether, as seems more probable, the greater strength depends upon the small percentage of silicon usually present, has not been fully determined by experiment.

Dr. R. J. GATLING.*—*Mr. Chairman and Gentlemen:*—I have read with deep interest the advance copy of the paper, "Aluminum Bronze for Heavy Guns," by Mr. Alfred H. Cowles. I will not attempt any criticisms of the author's views upon this important subject. I quite agree with him in all he has said in his valuable paper. I believe the coming large cannon will be a gun cast of either steel or aluminium bronze. I do not believe in "built-up" guns, for reasons given hereafter; such guns are more expensive to make, and are, in my judgment, not so safe, and are less durable than guns cast of steel or bronze. Built-up guns may be able to withstand the internal pressure that they may be subjected to, but the great objection to such guns is not only their cost, but their inability to bear the continuous shocks and strains produced by the force of the gases, and the vibrations and wave motions engendered at each discharge.

There are two kinds of vibration or wave motions produced at each discharge: one is produced by the force of the powder gases, and the other is caused by the recoil—the latter is quite as deleterious as the powder strains. In a built-up gun there are many joints in its exterior surface, and the vibrations and wave motions produced at each discharge are checked at the joints, and ultimately produce crystallization and weakness of the metal at such joints. These are facts which explain the short life of built-up guns. The great durability of the Rodman guns is not solely due to the way they are cast, but to their uniform and smooth exterior surface. Guns should not only be made of strong, tough, and springy metal, but should be, on their outer surface, free from joints or sharp angles. I will say in this connection, the lighter the gun the sharper will be the recoil and the greater will be the vibration or wave motions produced at each discharge; it is therefore better to have the guns of good weight (especially guns for fort use), so that the weight of metal may assist in taking up the recoil—one pound in the gun will do more to check and take up the recoil than two pounds in the carriage. I believe, as steel can now be produced cheaply and in large quantities, that heavy guns can be cast of that metal, or of aluminium bronze, on the Rodman plan that will be the largest, cheapest and best guns ever made. Such guns can be made, if necessary, of one hundred tons weight, to use a charge of, say, six hundred or seven hundred pounds of powder, and discharge a ball of a ton in weight, and have a range of ten or twelve miles. It is needless to say that such guns are greatly needed for the national defenses.

* The inventor of the Gatling gun, Hartford, Conn.

[illegible] and personally [illegible] that [illegible] should [illegible] Krupp is interested [illegible] other scientific men.

[illegible] new ideas [illegible] acquaintance in the [illegible] this direction [illegible] these [illegible] year [illegible] against [illegible] her repeating [illegible]

[illegible] which many think [illegible] said that [illegible] and our metal [illegible] European experts [illegible] that in this question [illegible]

[illegible] has excited the scientific interest of [illegible] for the American [illegible] there [illegible] avail itself of the advantage [illegible] a small fractional part of [illegible] ordnance that we now possess [illegible] that would so far surpass [illegible] endurance, and cheapness, [illegible] of Europe.

[illegible] to build guns [illegible] of steel intemperate [illegible] when such masses are [illegible] the gun?

[illegible] the following, published [illegible] January 22, 1887 [illegible] British Admiralty go to show that [illegible] the bursting of the [illegible] terrible loss of life, [illegible] well known.

[illegible] are not built.

[illegible] taken from the Boston [illegible] "The steel [illegible] The bursting of the [illegible] only [illegible] pounds [illegible] emphasizes the brittleness [illegible] the cruiser Colossus, [illegible] Mr. Krupp, who started

[illegible]

his 16-inch 120-ton steel guns so enthusiastically in the turrets at Spezzia, was chagrined to find, after 40 rounds, grave defects in the bore, and at the end of the 66 rounds the guns were in too dangerous a condition to continue at work. Both were condemned at a loss of $360,000. This has been the experience of steel for six years, beginning with the 100-ton Armstrong gun that burst in 1880 on the Duilio, and will no doubt continue, on account of the variations in temper that are sure to follow the twenty or more parts from which a steel gun is made. Even the last lot of 100-ton guns that Armstrong made for the Italian Government have, with their first usage, shrunk where they have been welded so as to let the water used to swab them trickle through, and so have all been condemned.'

Mr. William Metcalf, of Pittsburgh, one of our most distinguished American metallurgists, speaking of made-up steel guns, says:* 'The objections to this method of forging are its great cost, its uncertain results, and its limitations. By this method it is necessary to make a gun of many pieces, a built-up gun, because the whole gun cannot be hammered successfully in one piece. The cost of heating and hammering the various parts is large; and after this is done, each piece must be machined accurately and at still greater cost; and when the whole is assembled it is an unmechanical agglomeration of uncertain strength.'

It is a fact that the official evidence regarding the endurance of steel guns is extremely meagre. As Mr. Hunt, of the South Boston Iron Works, truly says: 'To be sure, there have been published by Armstrong, Krupp, and the Woolwich authorities, certain performances of their guns. With carefully selected powder, and where great pains were taken, an additional velocity of a few hundred feet per second was attained without destroying the gun. But such tests are not endurance tests, though they serve the purpose of advertisements.'"

The causes to which Mr. Cowles attributes the failures of steel guns, common sense would seem to affirm.

The effect upon a number of plates laid together when struck by a shot, as stated by him, may be further illustrated as follows. Lay a number of billiard balls in a level trough, all in contact. What will be the position of the balls after being struck by another ball which is rolled with considerable force against them? As is well known, the first and last ball come to rest at points farthest from the others, while the original positions of the remaining balls have all more or less changed. The tube of a made-up gun is the first ball—the hoops, the last.

Does it require any very subtle knowledge of the art of gun fabrication to see readily that where these external layers are already under great tension, approximating closely to their elastic limit, the stress which comes upon them is liable to exceed that limit, and, because of a small reserve in elongation, a complete rupture may take place? This tendency toward rupture of the external layer of the gun is greater than in the last plate of Holley's illustration, because in the case of the former a small distension of the metal at the bore means a much greater distension at the circumference, the extent being

*Army and Navy Journal.

proportional to the distance from the long axis of the gun. In spite of all precautions, certain portions of the external layer will give more compressional stress than others, because of variations in the temper, in the amount of machining to each part, and in the shrinkage; hence, those parts that are under the greatest tension have to bear "the full brunt of the blow."

When we consider these facts, does it not seem clear that toughness is what is needed in the external layers in order to ensure safety from explosion?

The amplitude of the vibrations of the reflected waves of distension being greatest, as Mr. Cowles points out, at the bore of the gun, may be sufficient to stretch the metal beyond its elastic limit, since the tube has the lowest elastic limit of any part of the gun. This may explain why it is we hear so much about the distortion and enlargement of the bore which so frequently prematurely disables the gun.

A good portion of the great elongation, now specified for the tube might well be sacrificed for a higher elastic limit. Indeed, while the tube as made serves as an excellent medium for the transmission of the waves of distension to the external layers, it fails, because of its weakness, to add its just proportion of stability to the gun. In a gun cast in one solid piece, all the sources of weakness described are avoided. No one can doubt that herein lies the secret of the remarkable success of cast-iron guns, not one of which, cast on the Rodman plan, has burst since the improvement of slow-burning powder in 1870. There are on record any number of tests made before 1870 of 10-inch and 15-inch smooth-bore cast-iron guns where the pressure has been registered as high as 100,000 and 200,000 pounds to the square inch, and where the endurance ranges from 300 to 2450 rounds.

Assuming that the gun of the future will be made from a solid casting, what advantages has aluminum bronze over steel and cast iron for this purpose? It is a recognized fact that castings of steel are more lacking in homogeneity or soundness than almost any other metal; besides, it is an utter impossibility to attain in a steel casting, even after annealing, the high degree of tensile strength, elasticity, and elongation combined which characterize certain grades of aluminum bronze. I speak from experience, being familiar with the metallurgy of aluminum and its alloys, and having seen large and perfect castings made of the bronze in question.

Among the advantages a cast gun of aluminum bronze would have over a steel gun would be that of its comparative freedom from the effect of crystallization from repeated shocks, which property in steel very likely accounts for many of the disastrous failures of the made-up guns, though it would undoubtedly prevail to a less extent in a solid steel gun were such a gun practicable.

In estimating ultimate cost, it must be remembered that the metal in a
out gun, a worn-out carriage, etc., of aluminum bronze is just as
ingot metal from which it was made, and can be melted up
without injury to the quality of the metal. With a wo
is quite different.
aluminum bronze with cast iron, it is sufficient to draw
higher degree of power and safety that is prob

in a gun of the former metal; and that, too, with considerably less weight, which factor is of importance, on board ship especially.

Gun carriages for heavy ordnance are made of steel in sections. If made of aluminum bronze the carriage could be largely cast in one solid piece, and be stronger and cheaper.

Armor plates of steel are very expensive because of the amount of work expended on them. A *cast* plate of the bronze should resist penetration as well as steel, while repeated shocks will not crystallize and finally crack it.

One of the disadvantages of the ordinary gun-bronze for ordnance has been that repeated firings had a tendency to recrystallize and dissociate the metals, causing, possibly, a complete liquation between the tin and copper. It is believed that this phenomenon would not take place in aluminum bronze, as that metal is considered a *chemical* alloy, and not a *mechanical* mixture.

It may be argued that, as the fusing point of aluminum bronze is considerably below the fusing point of steel or of iron, the highly heated powder gases at the moment of explosion would, if the firing be kept up, injure the interior walls of the gun. The test with the heated test-bar performed by Mr. Cowles and Lieutenant Hall, where the temperature of the metal was elevated to 400 degrees without apparently decreasing the strength, was certainly an encouraging one. It has been observed in rolling plates of aluminum bronze in a steel mill while hot that the metal is far more refractory at a dark red heat than similar plates of mild steel, though at a very bright red the case is reversed. From this it would appear that aluminum bronze is no more affected within the range of temperature to which the metal about the bore of a gun is subjected from the beginning to the end of a bombardment, than is mild steel, if as much. However, this is a question that should be satisfactorily decided by the Government.

In case it is found that in very heavy guns a steel tube is necessary, the bronze envelope cast in one solid piece being shrunk on after the manner adopted by the South Boston Iron Works for cast-iron guns, we should simply be substituting for the iron a metal three times stronger combined with great toughness, whose coefficient of expansion and heat conductivity would be so near that of the steel tube as to reduce any strain arising from heating to a minimum.

Mr. Wm. H. Brown.* *Mr. Chairman and Gentlemen:*—The paper of Mr. Cowles upon "Aluminum Bronze for Heavy Guns" calls up the fact that in alloys it is impossible to obtain a constant composition. In casting bronze metal, the temperature of the casting and the method of cooling have a great influence on the qualities of the alloy. Slow cooling diminishes the strength very much, and a reductive powerful enough to eliminate all the gases is necessary. The use of the oxide of aluminum may aid in the bronze production, as much as phosphorus has done, and may be equally valuable, as an alloy, in steel, as is claimed for it; but the fact remains that a *uniform fixed composition* cannot be obtained, for the metals will separate into alloys having different proportions, which weaken their value and reliability. I caused,

* Manufacturer of Seamless Steel Tubes, Jersey City, N. J.

years ago, an alloy to be made of aluminum and copper and had it tested at the Frankford Arsenal by the late Col. Lyford, then in charge there. It was made into cartridge cases, and is a matter of record. It is enough here to say that in some respects it was an improvement; but in resistance to shock of firing and endurance it was no material improvement. If a fine wrought metal of copper and aluminum, carefully prepared by experienced producers, did not, by the addition of the aluminum, show any improvement against the shock of explosion, how can a casting with a cavity show such improvement as Mr. Cowles claims for it? The built-up gun of Capt. Blakeley's conception, mentioned by Mr. Cowles, and the wire gun, will be reached, at no distant day, by placing one steel tube over another, thus overcoming the want of longitudinal strength in the wire gun, and giving any grade of temper that the tensions of the metal demand to meet the strain of explosion, besides making secure the hoops and tube bore of the gun. The difference in cost of construction must be largely in favor of steel, and the difficulties attending the bronze construction largely surpass steel. I am a convert from alloys to pure metal in all construction, although a worker of alloys all my life.

P. A. Engineer G. W. BAIRD.—*Mr. Chairman and Gentlemen:*—I desire to give you a brief sketch now, and I trust more at a future day, of an aluminium bronze reel I designed for the Fish Commission. The reel was for a sounding machine to carry about 5000 fathoms of No. 28 piano wire, and it was essential to get as little weight into it as possible. Our built-up steel reels had not been altogether satisfactory, and I believed we could do better in this new bronze, which was represented as particularly strong. To insure the best possible casting, I informed the Cowles Electric Smelting Company of the purpose for which the reel was to be used, that the pressure upon it would be crushing and not tensile, and gave them the order to make the casting from our pattern. I was not able to obtain from them the actual crushing strength of the metal, though I asked. The percentage of aluminium was left entirely to the Cowles Company. We obtained a fair casting. It was a difficult casting to make, and I feel sure that the metal flows quite as well as any of the bronzes. In finishing the casting we discovered that one side was much softer than the other, from which I infer that the metal was not thoroughly mixed, and it is my belief that a test specimen cut from each side of our reel would give quite different physical results.

Our reel has been tried and has answered its purpose [illegible] crushing stress has been on it I cannot even estimate, as ab[illegible] 3500 of wire were wound on at a low tension, and after sounding in 2000 latter quantity was rewound at a tension varying from 80 p[illegible] to [illegible] While I would be glad to urge the use of this alloy for reels for s[illegible] machines, I should advise great care in mixing and pouri[illegible] heavy guns. It is easy to see what an enormous advantage it has [illegible] respects over iron or steel for guns. It is apparent that we could re[illegible] Navy at much less cost and in vastly less time by the substitution of al[illegible] [illegible]e for the built-up steel guns our people are now struggling [illegible]

some embarrassment in offering advice in the matter of material for guns, as it is so foreign to my calling; but it is a matter which affects the service as a whole, and I trust my experience with the reel may be of use to those who are building the great guns for the coming navy. While my words may be construed as testimony against the bronze, I do not wish to be understood as saying or believing this trouble is insurmountable; on the contrary, I believe that with experience these two metals (copper and aluminium), which have such a difference of density, will be alloyed with great success.

Mr. J. R. HASKELL.*—*Mr. Chairman and Gentlemen:*—Having been honored with an invitation to be present and to take part in the discussion on the paper on "Aluminum Bronze for Heavy Guns," by Alfred H. Cowles, or to send my "opinions and criticisms in writing" in case it should be impossible to be present, I have the honor to inclose this communication in compliance with that request.

There are two questions in regard to the construction of guns: First, the kind of metal of which they should be made; and second, the manner of construction. The first of these propositions only is to be considered in this paper, although the latter is perhaps of more importance than the former.

I have examined closely into the subject of the best metal for the construction of heavy guns, and I place them in the order of excellence as follows: 1st, aluminium bronze; 2d, cast iron; 3d, steel.

In stating this order of merit for the metals a good deal will depend upon the manner of constructing the guns and projectiles, but I am convinced that if the guns are constructed upon the proper plan, the order of merit for the different metals will stand as I have stated them. I give this opinion based on a practical experience of a third of a century spent in constructing and experimenting with breech-loading rifled ordnance and projectiles. I have my own idea of the best way of constructing guns, but that subject is not under consideration at this time, although it has an important bearing upon the question of what metal is best to use.

In the paper of Mr. Cowles, now before me, he has stated the advantages of aluminium bronze as a metal for constructing heavy guns, in which statement I fully concur. He has given a table showing the physical qualities of the metal, which shows it to be fully equal to steel, if not superior; and at the same time he demonstrates that it possesses other qualities which steel does not, which makes it superior to steel as a metal for constructing guns.

In making guns of ordinary gun bronze, they must be made of new metal, and good bronze cannot be made of old guns, as the tin burns out in remelting, and the exact proportions cannot be arrived at. A certain proportion of zinc has to be used as a flux to aid in uniting the copper and tin. I am aware that the Ordnance Manual of the Army gives 9 parts of copper and 1 part of tin as the composition used, but all the bronze founders I have employed say that a little zinc must be used as a flux. Now, in making aluminium bronze no flux is needed, as aluminium thoroughly unites with the copper, and with all other

* Inventor of the multicharge gun.

... castings can be made with ... when alloyed with ... at the centre of the per- ... the tests can be per- ... of wrought iron. The ... over again in the ... metal.

... that steel or cast iron ... after they are cast will ... there will be less ten- ... of the guns, as they will ... guns are fired with ... does not allude. ... large guns have burst in the ...

... have recently ... than others, and ... there is a per- ... but there is a ... In this respect it is ...

... aluminum bronze over any ... determined to make an ... by the Cowles Electric ...

... which I do not approve, and ... prove an injury to his ... and give my reasons for ... system of casting ... around the bore. ... of the adoption of ... this adoption has given ... deserve. I refer to the ... from the centre. The ... commencement—never a ... from the inside, which was ... and inside. It is true ... the pretense of keeping ... from the inside, and ... pipe in the centre of ... I have been informed, that ... loosened the sand ... abandoned. One fact, ... pretense of heat outside the ... the flask red hot to prevent

outside cooling. In the cooling of guns, the parts that remain fluid or red hot the longest give way to the parts that first become cold or set, and the shrinkage draws apart the red-hot metal and produces cracks or porous places in the metal where the greatest degree of heat remains the longest.

The diagrams below show the effects produced in the cooling of large gun castings. Figure 1 is a cross section of a gun cast solid, and shows the effect

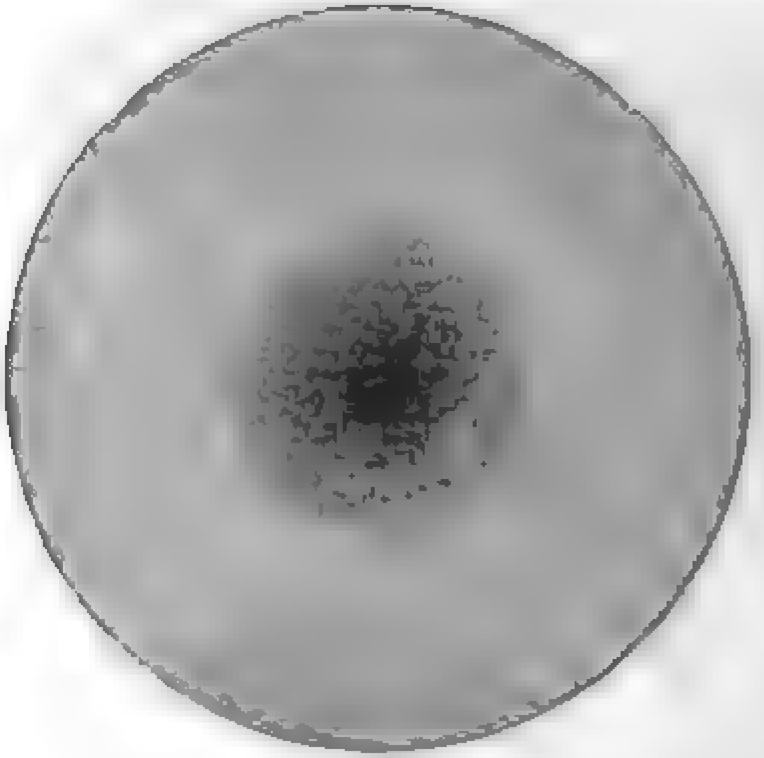


FIG. 1.

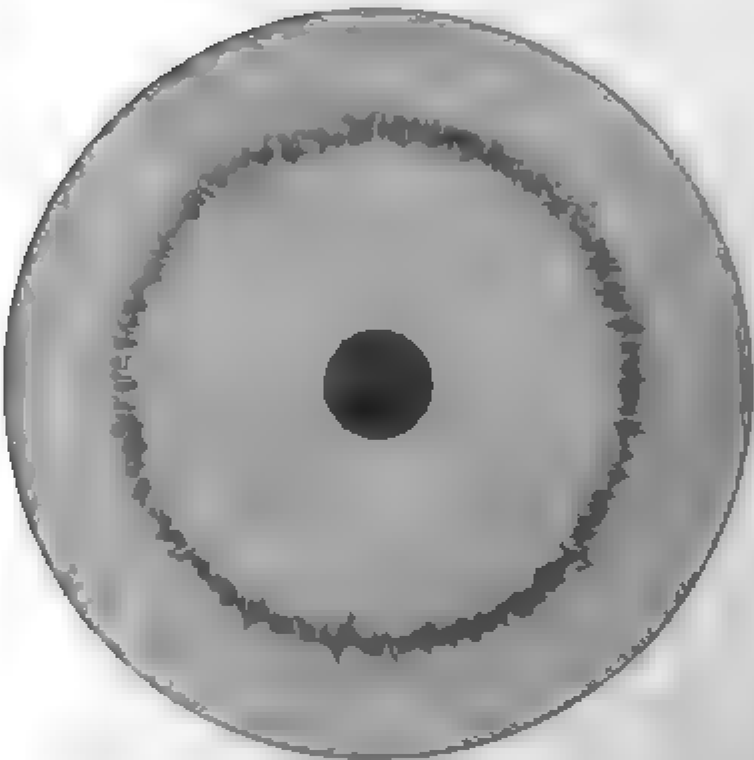


FIG. 2.

on the metal of cooling from the outside, in which the inside metal remains fluid the longest, and the drawing apart and checking take place in the centre. In this case the injured part of the metal is bored out in finishing the gun, leaving the solid metal surrounding the bore. This is the manner in which the Dahlgren guns were cast. Figure 2 represents a cross section of a gun cooled from the centre on the Rodman plan. In reality the gun is cooled from the centre and outside also, and the cut shows the effect on the metal when the parts which are hot the longest are those surrounding the bore. Guns cast in this manner are not as strong or durable as those cast solid and bored out.

This Rodman system of casting guns was forced into the Navy against the protests of Captain Dahlgren, one of the ablest ordnance officers in the Navy, and whose guns cast solid had never been known to fail. Captain Rodman had some 10-inch guns cast solid, which he caused to be made in such manner as to produce failure, in order to aid in securing the adoption of his system. The guns, however, which were made under the direction of Captain Dahlgren at the same time all proved good, none of them having failed.

The patent of Captain Rodman was for casting a gun hollow and cooling the casting from the inside. The Rodman gun was adopted for the United States service upon the result of a trial during which fifteen guns were cast and proved, *of which eleven burst.* (See Rodman's Experiments, page 133.)

Colonel Bomford had made a 12-inch gun in 1845. It was fired 100 rounds with the severe powder in use at that time, and was not injured in the least. It was of larger calibre than had ever before been attempted of cast iron for a smoothbore cannon, and no rifle of large calibre was then contemplated by Captain Rodman or any one else. The account of the test of Colonel Bomford's gun can be found on pages 111 to 123 of "Wade's reports of experiments on the strength and other properties of metal for cannon: by authority of the Secretary of War, 1856."

None of the guns cast hollow and cooled from the interior previous to the adoption of the Rodman plan (1859) were of larger calibre than 10 inches.

As smoothbore shell guns, no cannon of large calibre had ever exhibited better endurance than the guns *cast solid* and cooled entirely from the exterior, designed and made under the direction of Captain Dahlgren, especially after they had their injurious tensions relaxed by age—that is, by exposure for years to the mollifying influence of the elements. The changes of temperature from night to day, from winter to summer, had annealed them. After this they could be fired with heavy charges of the most severe powder, and as rapidly as the most exacting conditions of battle required.

Admiral Porter said, in a paper laid before the Joint Committee on
40th Congress: "I have never known an accident happen to the 9, 10, or
inch guns, three of the best guns we have ever had in the Navy, and
men stand behind these guns in perfect security, knowing that the
their bursting is very small." These were Dahlgren guns cast solid a
from the exterior.

On this subject, Captain James Alden, U. S. N., testified before the Committee on the Conduct of the War, January 23, 1865, as follows:

By the Chairman :—*Q.* What number and calibre of guns had you on board the Brooklyn in your expedition against Fort Fisher? *A.* We had twenty 9-inch guns, two 100-pounder Parrotts, and two 60-pounder Parrotts—all four of the Parrotts rifled.

*Q.* How many times were those guns fired in the two attacks upon the fort? *A.* I threw into the fort 3400 9-inch shells—over 120 tons.

*Q.* How did the guns bear that shelling? *A.* As soon as I heard of the 100-pounders bursting, I put mine on the opposite side of the ship from that from which I was firing, and put in their places the 9-inch guns, so I had twelve 9-inch guns in battery all the time.

*Q.* Then you did not use those 100-pounder Parrotts? *A.* Not after I heard of the accidents with them on the other ships. I never fired them again.

*Q.* Were those 9-inch guns made on the Rodman principle? *A.* They were Dahlgren guns.

*Q.* Were they cast hollow, or otherwise? *A.* They were the Dahlgren 9-inch guns—the best guns ever made.

*Q.* What effect had the firing upon them? *A.* I never discovered that any of them were injured.

*Q.* Did none of them fail? *A.* Not in the slightest degree. The men stand around and fight with them with as much confidence as they drink their grog.

With regard to the improvement of the model of the Rodman gun, Admiral Dahlgren resented it as a plagiarism, and in a letter addressed to the Secretary of the Navy protesting against the adoption of the hollow mode of casting for navy guns, printed in the report of the Joint Committee on Ordnance, Senate report committee, No. 266, Fortieth Congress, third session, he said: "I think what Mr. Parrott here states admits of neither question nor qualification. Please to note that the solid-cast 11-inch gun, cast not with any special care, but with no more than is usual in current manufacture of a large number, gave 'more uniformly satisfactory results than the hollow-cast Columbiads of old model, to which the experiments of Major Rodman were for a long time confined.'

"Now note what Mr. Parrott says a little further on: 'But a further experiment was made after the model of the 10-inch Columbiad had been changed, by rounding off the angular breech and giving increased thickness at the bottom of the bore. In this instance both solid and hollow-cast guns endured well, reaching 4250 rounds each without bursting.'

"The plain and direct conclusions from these statements are: 1. That when Major Rodman's mode of hollow casting was applied to the army Columbiad of the old model, my solid-cast 11-inch gave more satisfactory results. 2. And that when the model was changed there was obtained a very striking advantage to Major Rodman's hollow casting. It went 4250 rounds. This would have been a stubborn fact to overcome by itself; but it does not stand by itself, for a gun of exactly *the same improved model was cast from the same furnace, the same iron, and cast solid as the 11-inch guns are cast.* That, too, endured just the same amount of firing as the hollow cast, namely, 4250 rounds.

Well, from all this follows: 1. That hollow casting would not save a bad model. 2. That when the bad model was changed to a better, the solid-cast gun endured just as much as the hollow."

The second point in Mr. Cowles' paper to which I object is his proposition to make use of the "Dean process" for condensing and hardening the metal immediately surrounding the bore of the gun. I am opposed to this as entirely unnecessary and an alleged improvement in the wrong direction. Mr. Cowles, near the commencement of his paper, in giving the qualities which a good gun metal should possess, says, "And its walls should be hard enough to withstand the abrasive action of the projectile." No shot should be used in a rifled gun which has an "abrasive action" on the inside of the gun, and the improvement needed in this direction is not a condensation of the metal surrounding the bore to resist this abrasion by the shot, but an improvement in the projectile itself, and in the rifling of the gun to permit the use of a projectile that will not cause abrasion, but which will be delivered from the gun without injuring it, even as much as a round shot delivered from a smoothbore cannon. The use of such a projectile with a minimum amount of friction will render superfluous all such application of additional strains on the gun to harden its interior.

Mr. Cowles no doubt thought that such a process of interior hardening was necessary because of the effect on the guns of the projectiles now in use in Europe and in this country, and the system of rifling adopted. These are radically wrong, and in order to make this appear more conclusively, and to show how entirely unnecessary is the use of the "Dean process," it will be appropriate to review these systems of rifling and projectiles as now used, and to show wherein they are defective.

The rifling in use in Europe, and imitated in this country, and the projectiles with their manner of taking the grooves, are not made on scientific principles, and are in fact a violation of well known mechanical principles. The rifling starts at the breech with a very slow twist, and then commences to increase in its twist or pitch and keeps on increasing until it gets within a foot of the muzzle, when it becomes uniform from that point to the muzzle; in other words, when the projectile is going comparatively slow the rifling is almost straight with a very slow twist, but the higher the velocity becomes the quicker the twist. To illustrate: if a curve commences on a railroad track at first with very slight curve, run the engine very slow; as the curve becomes sharper run the engine faster, and at the sharpest part of the curve run the engine the fastest! This is the system on which the guns now being constructed for our Government are being rifled. There is neither science nor common sense in such a system.

The projectiles in use in these rifled guns are even worse than the rifling; they are of two kinds, either expanding or force—*i. e.* slugging projectiles, where the bore of the gun acts as a die in which the shot is forced through, imprinting on the shot the grooves and lands of the rifling.

A distinguished officer of the English Navy, and author on the
ballistics, Captain Dawson, R. N., in a paper read before the Ro
Service Institute, said, referring to the "Woolwich Infant" in 1873 (
been disabled), ten years after the adoption of that unburstable
system: "Thus in the course of thirteen horizontal discharges, spre
five weeks, maximum pressures are evolved from two i
Waltham Abbey Pebble (powder) charges of 20 and 60 tons respe

problem of the Surveyor-General of Ordnance might well assume a different form, for it is not a question here of different amounts or different kinds of powder, of different elevations, or of different chamber temperatures. Every condition is identical. The gun was carefully nursed on both days. It was the third horizontal discharge on each day that we are comparing, and we may assume that the intervals between the discharges were equally large, yet 3½ times greater pressure is registered on one occasion than the other. Why is this? Again I ask, has any powder manufacturer found that carefully made gunpowder varies in its explosive force to the extent of 3½ times the pressure? Do shells explode with 3½ times their wonted violence without cause? Do torpedoes manifest eccentricities to this extent? Do miners find that identical charges of similar powder, fired under like conditions, explode with 3½ times their usual force? Vary the question as you will, nowhere but in a Woolwich rifled gun containing a non-centering shot balanced in unstable equilibrium upon two points, and restricted to a short rifle bearing of one inch in each groove—in these, and these only, do similar charges, fired under like conditions, produce such anomalous results.

There are, of course, waves in a gun, just as there are waves in the sea; but when the waves of the sea singled out and engulfed a particular ship in the midst of a squadron, the common sense of seamen told them that the fault must have been in the ship and not in the waves. And when gunpowder plays such pranks in a gun, every intelligent gunner knows that it is not the gas waves but the *shot* which must be at fault.

Again we are told that it was 'intense wave pressure' and 'local action' which disabled the gun. Now this 66-ton pressure was registered more than 3½ feet from the spot where the whole of the injuries are concentrated. And if the shot had centered itself in the bore, even the 53 tons pressure on its base could not have reached within several inches of the damages, so that it is perfectly clear that it was not the direct action of the maximum powder pressure which disabled the gun, but the mechanical movements of the shot acted upon by these great pressures—the two forces—viz. the wriggles of the shot and the combustion of the charge, acting and reacting upon each other."

The projectiles now in use in this country for rifled guns are the same "gun destroyers" so strongly condemned by this able writer on the science of ballistics, and if the United States would save millions of dollars and years of time, the voice of experience and science must be heeded. The increasing or gaining twist makes it necessary to use the objectionable projectiles before referred to by Captain Dawson, R. N., as "non-centering shot balanced in unstable equilibrium upon two points, and restricted to a short rifle bearing of one inch in each groove," etc. In using the gaining twist the bearing must be *short* and restricted as stated, and this is a vital objection to that system of rifling. More guns are destroyed by the use of improper projectiles and rifling combined than by the pressure of gunpowder.

Besides, the immense friction and strain developed by these projectiles not only destroys the guns rapidly, but this same friction robs the projectile of just so much of its energy in striking the enemy.

In May, 1864, Captain Fishbourne, R. N., stated to the United Service Institute, London, "That it required 40 tons of pressure to force an Armstrong lead-coated projectile, of 25 pounds weight, slowly through the bore of a breech-loading rifle gun of that calibre." What then would be the amount of pressure required to force a shot weighing 500 pounds through the bore of a gun in the $\frac{1}{100}$ part of a second? How rapidly would this immense friction rob the shot of its power and tend to destroy its own gun instead of the enemy?

All this friction is unnecessary. A projectile properly made, mechanically fitted, and centered in the bore of the gun, can be drawn through the bore by one man with a small cord. With such a projectile the gun will be preserved, and the projectile will keep all the power given to it by the pressure of the powder gases until it leaves the muzzle.

The gun should be rifled with a *uniform* twist, thus giving the entire twist to the projectile while it is going at its lowest velocity. The shot should be one *that does not alter its shape in the gun*, should be mechanically fitted and centered in the bore of the gun, which will prevent all wedging, wabbling, and balloting in the gun, insuring accuracy of flight through the air, meeting with less resistance from the air than the wabbling projectiles, even if these latter kind do finally centre themselves through their rotary motion in the air. The rifling should be so cut as not to weaken the gun, and to admit of the use of anti-friction projectiles, in order to prevent the destruction of the gun by immense friction, and waves of enlargement running through the gun with the velocity of the projectile, thus robbing the shot of a large portion of its energy by this unnecessary friction.

Mr. Alfred H. Cowles.—*Mr. Chairman and Gentlemen:*—The papers read this evening seem to show that there has been a misunderstanding as to the position held by me on the "built-up" gun. No matter how small an improvement can be made, expense in gun fabrication should not be spared in making that improvement. This is true to a very large degree; and, as stated, the built-up gun shows from my point of view about thirty-three per centum increase in efficiency over the old cast-iron guns. This improvement gives ample justification for the additional expense incurred in building up guns of steel.

One of the gentlemen stated that the coefficient of elasticity
is one of the banes of existence to the artillery engineer who des
up" gun, and that it will perhaps be a surprise to the lecturer to
same coefficient will be harder to handle in casting than shrinking.
the cast guns of weak material have done so well; but this feature
handled once there, where it may enter into the calculations twenty
building up a gun. Ensign Glennon remarks that the deviation in
mentioned by me is $\frac{1}{2000}$ to the inch. It is not surprising that he
been misled, as there was an error in the copying of my manuscript,
$\frac{2}{1000}$ was made to read $\frac{1}{2000}$; however, an error of $\frac{2}{1000}$ of an inch
meter of a 17-inch ring causes a wrought-iron built-up to
entum of its calculated strength, which is equivalent to the
being in repose. With steel a little more leeway would
extension is a little greater than wrought iron. Mr. Glennon

"Why not start with a mild steel of 70,000 pounds tensile strength, 30,000 pounds elastic strength, and thirty per centum elongation, and subject it to the mandreling process? What is there in this process that would apply to aluminum bronze and not to steel?" There is nothing. If you can obtain the cast steel in the form of a large and perfect gun casting, mandrel it by all means. It is the most perfect way of obtaining a nice system of varying elasticity from the centre outwards. Mr. Glennon says it is already practiced on the mild forged steel tubes of large guns. He, however, has selected the form of steel that is most difficult to cast. Its melting temperature is more than twice that of the bronze and higher than hard steels. It absorbs gases when molten and gives them off on solidifying. Krupp may properly be called the father of the method of casting large masses of steel. His first guns, which were failures, were cast-steel guns. Until the time of his death he kept abreast with all improvements in the metallurgy of steel, but was never able to return to his early and ideal method of obtaining solid guns of steel. Mr. Glennon is further inclined to class aluminum bronze with ordinary gun bronze, and attributes to it a tendency in its elements to separate during solidification, or from the effects of heat and vibration. The able papers of Professor Thurston and Professor Mabery will undoubtedly give him more information on this and other points. As to his criticism that the metal in the tube of a gun must withstand a temperature between 3000 and 4000 degrees Fahrenheit—this is true, but it is for only the one hundredth part of a second. Faraday demonstrated that in the flame of a candle a fine platinum wire could be melted, showing an equally high temperature; yet one may thrust tissue paper within that flame and it will not ignite unless it has many hundredths of a second for the minute films on its surface to become heated. Time is an important element in determining the amount of heat one body will conduct away from another. The molecular movement of the metal in the walls of a gun is sufficient to account for the rise in the temperature of the gun, and this tends to distribute the heat throughout the whole thickness of the walls. The effect of the friction of a rifled ball can only be determined by use and experiment. A steel tube would obviate any difficulty that could arise within the bore of a gun, and would supply a remedy if needed.

Thanking you for the interest manifested, I close, resigning the cudgel to my brother, Eugene H. Cowles, who, at a later date, will answer more in detail the objections that have been raised to the use of aluminum bronze.

The CHAIRMAN.—In the brief remarks that I have to make this evening, I shall not enter upon any discussion of the qualities of aluminium bronze or of its suitability for purposes of gun construction. But I wish to direct attention to a radical misconception which seems to me to lie at the base of much of the argument which has been lately heard, here and elsewhere, upon the subject of a proper material for guns.

The gentlemen who within the last year have appeared before this and other audiences to propose substitutes for the material now used, have based their recommendations, first of all, upon the assumption that a new material is urgently necessary, that now in use having shown itself hopelessly unreliable.

This assumption they do not attempt to establish by the citation of evidence, but content themselves with such statements as the following from the paper of this evening, "I need not refer to the many failures of steel guns," etc. As the lecturer is dealing with guns of the present day, and not with those of twenty years ago, it is fair to assume that when he says "steel guns" he means such steel guns as are now in use; that is to say, steel *built-up* guns.

I have no doubt the sentence quoted was written in perfectly good faith, and that the lecturer believes that a large number of built-up steel guns have burst. This is a belief very commonly held, even among people whose sources of information ought to be reliable. It seems to rest to a great extent upon a widespread but entirely erroneous idea that the artillery of England is principally of steel, and that the frequent accidents reported from English ships and forts have been in steel guns. The fact is, that the number of steel guns in service in the English Army and Navy is quite insignificant in comparison with the number of wrought-iron guns.

About the beginning of the present year a return was made to Parliament of the number of English guns that had failed in the twelve years preceding. The list includes 31 guns, designated by their numbers and marks. A comparison of the list with a descriptive table of ordnance issued by the War Office, shows that of these 31 guns only two were of steel: the 6-inch gun of the Active and the 12-inch gun of the Collingwood. To these should be added a 9.2-inch gun which failed in trial.

Reports have been frequent of the bursting of Krupp guns, but, so far as I can learn, only one such report is capable of confirmation. This is the case of a 10-inch Krupp gun which burst at Fort Heppens in 1884. It will be understood that I still speak of *built-up* guns, the manufacture of which by Krupp dates from 1872.

To the four examples cited above of all-steel built-up guns which have failed in service or test, must be added a DeBange gun of 42 centimetres calibre, the muzzle of which was blown off in France in 1885.

The large number of built-up steel guns which are authoritatively recorded as having burst reduces itself, then, to five. With regard to these, it is interesting to note that without exception they failed only in the chase, forward of the hooping; that is to say, at the point where it had been attempted to give the necessary strength by a single ingot unassisted by the building-up principle. In every case the fracture of the tube was stopped short at the first hoop. In fact, the DeBange gun mentioned was reported as entirely serviceable after the accident, and other guns have actually been built upon the model presented by this gun after he loss of its nineteen inches of unhooped muzzle.

Such a thing as the failure of the built-up portion of a steel gun is, I believe, absolutely unknown; and all authorities who have discussed the accidents quoted above have been forced to the conclusion that the guns would not have failed if the hooping had been continued to the muzzle, as it is in the latest designs.

With regard to the lecturer's statements that to realize satisfactorily the con- ; involved in the principle of initial tensions "is generally conceded to :chanical impossibility," and that "practical men consider the nicety of

workmanship required for this as impossible of attainment," it need only be remarked that Sir Joseph Whitworth, Sir William Armstrong, and Herr Krupp have been generally conceded to be practical men, and they have all believed that the construction of such guns was not only possible but very simple.

The lecturer says that cast-iron guns have been known to stand pressures far above the tensile strength of the metal without apparent rupture, but it is doubtful whether or not a steel gun has ever stood such a pressure. As the tensile strength of the steel in question is about 43 tons, the lecturer would probably have been safe in saying that no steel gun has ever stood such a pressure, and he might have added that no steel gun will ever be called upon to stand it. And this would seem to be a point in favor of the steel.

On the motion of Commander Harrington, seconded by Commander Sampson, the thanks of the meeting were unanimously tendered to Mr. Cowles for his interesting paper.

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The following paper, in reply to some of the foregoing criticisms, was received November 13, 1887:

Mr. EUGENE H. COWLES.*—A careful review of the criticisms that have been made against the proposition to substitute aluminum bronze for steel in the manufacture of heavy guns, shows that our position on certain points is not quite clearly understood by some of the distinguished gentlemen who have honored the discussion with their opinions.

The most important misconception that has arisen appears to be that we have the idea that the old system of cast or wrought-iron ordnance might better have been perfected and adopted than the present system of "high power, all steel, built-up guns." Nothing could be further from the position we hold, or from that advanced in my brother's paper. If we had not held the opinion that the present system of heavy guns is the best that the world has thus far seen, the able remarks of Lieutenants Knight and Gleaves would certainly have convinced us of that fact.

The many references to cast-iron guns were made only to emphasize the fact, that notwithstanding the comparatively poor material of the old solid cast-iron guns, the gain in work done by the new "built-up" steel guns was not proportionate to the higher physical qualities possessed by steel over the cast iron. In other words, a gun of steel of 90,000 pounds tensile strength and of proportionately high limit of elasticity gives us only about forty-five per cent more efficiency than a gun of cast iron of 30,000 pounds tensile strength and a low limit of elasticity, although the steel has fully two hundred per cent greater tensile strength and a much higher limit of elasticity than the iron; and this, too, regardless of the fact that the most perfect and costly workmanship of the world has for the past generation been vainly employed to apply the principle of "initial tension" to the fabrication of "built-up" guns. That

* Member of the Royal Institution of Great Britain, and of the American Institute of Mining Engineers.

solid guns of iron, steel, or tin bronze, either wrought, cast, or forged, should not have been able to keep pace with the rapid advances made in "built-up" guns is perfectly natural. Indeed, when we consider the numerous, and to a somewhat large extent contradictory, physical qualities that must be possessed in combination by a proper material from which to make a solid gun, it could not have been possible that the solid gun should have succeeded in holding its own, when only iron, steel, or tin bronze were at hand from which to construct it.

With these facts in view, and having clearly in mind the reasons why solid guns in the past have not succeeded, the proposition was made that a solid gun can now be constructed of aluminum bronze, because in this alloy is found a combination of all the good qualities of iron, of steel, and of tin bronze, with none of those elements of failure that have heretofore rendered it impossible to make a successful large gun of a single piece. These qualities, physical and chemical, many of them contradictory in other metals, together with the economic advantages, are as follows: A remarkable combination of maximum tensile strength, hardness, ductility, elastic limit, stretch within the elastic limit, compression strength, tenacity, and malleability when hot; of freedom from liquation, freedom from difficulties in casting, non-corrodibility, minimum weight, minimum cost, of shortness of time required for construction—a matter of great importance to Government economy—and finally, the maximum intrinsic value of the metal when the gun is rendered obsolete or injured.

The above claims many engineers may regard as extravagant, and we be slow to put them forward, were it not that they are the deductions of two thousand carefully conducted and recorded examinations of the prope the alloys of aluminum and other metals. Each one of these e embraced from four to ten distinct physical and chemical tests of and all the important results obtained by us we have had ca and repeated many times by eminent experts both at home and abro scarcely necessary to add that this work has involved dollars, not including the half million dollars invested in pla for mercial production of these alloys.

It is, therefore, with some experience and much confidence that we that, if the old cast guns failed and were not as good as the présent "l guns, it was because they were made of cast iron instead of a and further, that, if the Uchatius mandreled guns only held their o 1886, and up to 6-inch size, it was because Uchatius used tin b metal instead of aluminum bronze. While still holding the view gun can be made from a single piece and that it is simply a matter of time, money, brains, and a proper metal from which to fabricate it, to be good reasons to believe that the substitution of aluminum br steel, even in the construction of built-up guns, would be a gr

The high elastic limit and tensile strength and ductility of alun a result of the aluminum contained in the bronze, and, in the case of work done on the same, and not largely that of temper, as

has not those uncertainties of strength and tendencies to brittleness which so good an authority as Mr. Daniel Adamson, of the British Iron and Steel Association, in his presidential address, no longer ago than May, 1887, said were liable to be found in steel. At that time he stated that "the greatest evils that have befallen steel guns have arisen from the material used, being composed of too strong a metal having little ductility and special weakness at low color heat, and at best, a material not calculated to resist concussive shock induced by the explosion of gunpowder."

Farther, it can be remarked, as a supplement to the observations of Ensign J. H. Glennon on the matter of ductility in a gun material, that ductility is a reserve of safety that cannot be ignored, especially in a built-up gun, and the higher ductility of aluminum bronze would render it more valuable than steel in a built-up gun, always allowing that the elastic limit and hardness were as they are, proportionately higher in aluminum bronze than in steel. Right here it may be well to introduce a further quotation from President Adamson's address, where he says: "Taking the elaborate discussion on Mr. Dorsey's paper in America, the artillerists may be said to take the view of adopting a strong steel, while the civil and mechanical engineers desire to use a lower and milder steel with much more ductility. No two opinions can exist that the fundamental principle to be observed in the selection of the material to be used for this purpose in the future must be such that no probability will arise that a gun will burst until so disorganized as to render it incapable of further use."

In regard to the question that has been asked, Why would not the Dean process of mandreling apply to the making of a solid steel gun from a mild steel as well as in the case of aluminum bronze? the reply can be made that perhaps it would, although blow holes are not found in aluminum bronze as in steel castings.

In point of fact aluminum bronze in itself has no affinity for any kind of gas to be met with in the casting process, nor does it occlude gas in the melting, as does iron or steel. At times blow holes will occur in castings of this bronze, but they are invariably caused by the air or steam from a wet mold becoming entangled in the metal in a mechanical manner. Aluminum bronze, when cast in ingots in chill molds that are free from oil or gaseous facing matter, the metal being poured in a quiet, steady stream that does not foam, and through the bottom of a secondary or straining pot, is always solid and perfect—a conclusive evidence that the metal does not occlude gas. Steel cast in this manner with the same care is always more or less spongy. The blow holes, as Dr. Gatling suggests, may be gotten rid of by the use of aluminum in the steel casting process, but only actual working experiment will determine whether or not it can be accomplished. The success that many steel founders are making with the ferro-aluminum alloy produced at Lockport, N. Y., would tend to show that efforts in this direction would result in the soundest castings that have yet been made of steel.

It has now been shown that, as advocates of the aluminum alloys for ordnance purposes, the position of Mr. A. H. Cowles, as well as that of the writer,

is one preferably in favor of solid aluminum bronze guns, solid aluminum steel guns, or, if we have to make a virtue of necessity, we should favor the use of aluminum alloys either of copper or steel in the built-up gun. In other words, we have such strong opinions as to the value of aluminum when added to other metals, that we are aluminum men first, last, and all the time, until actual practice shall have demonstrated our theory on this subject to be erroneous.

As to the advisability of the Government making an investigation of these alloys, it has been objected that there is no urgent need of a new material for guns. To this it is only necessary to say that the time never has been yet that man has refused to accept a better weapon of defense than the one he already possessed without in the end paying dearly to some conqueror for his short-sightedness; and it is not now likely that the world in this unexampled age of progress is going to rest content with steel if there is the smallest chance of obtaining a better material. No, we must move on and on, and the gun, or that particular material for a gun, that is regarded as perfection to-day, to-morrow may be obsolete, and in a generation may be looked upon as a relic of ignorance and inexperience.

Since the the war of the rebellion these changes have b
cast-iron guns have given way to wrought ones, to compound c and
cannon, to wrought-iron and steel guns, finally to all steel. G
have given way to those of forged steel, forged steel to "b g
guns to long ones, smooth-bore guns to rifles, muzzle loaders to bre
large-bored guns to those of smaller calibres, and so it is
end of time. For this very reason attention has been c d to
value of aluminum bronze. During the past twenty-five y re
probably been fifty or a hundred cannon rendered valueless by
changes going on, to one that has actually been destroyed
sea. With wrought iron or steel the loss that has thus occurred
ninety per cent of labor spent in fabrication. Had these old
been of cast aluminum bronze, fully two-thirds of this loss w
happened, and the old guns, instead of having been used for f
scrap, etc., would have been recast into more efficient weapons
It is not, however, intended by this remark to convey an idea
should govern in selecting a material for guns rather than
material and that process is infinitely the cheapest that is the best.
ment is advanced simply to show the happy advantage poss
respect by aluminum bronze coincident with its other superiorities.

With regard to its cost, sixty cents a pound would be an a
price for it in a finished cast gun. If it is true, as it has been stat
Hotchkiss gun, which sells for something like two or three do
can be made for much less than forty cents, it is a most substantial rea
there should be a little competition in the United States in
n bronze. The statement made in the opening paper of the
the cost of steel guns, has been criticised as be
rnments at home and abroad. This is exactly as

understood. The cost to the Government is the selling price of the manufacturer, no matter how low the cost of production happens to be. In some cases, where the Government manufactures its own guns, it may save the manufacturer's profit. In this country, where the work is partly private and the rest done by the Government, the estimate that was made on the cost of steel guns was certainly not too high. In proof of this take the following figures for the unfinished gun steel forging contracts made this year; they surely do not represent more than the first half of the cost of the finished gun. They are as follows: Bid of the Cambria Iron Company on 1310 tons, \$851,513.90 = 32.5 cents per pound. Bid of the Midvale Company, 1310 tons, 1,397,240 pounds = 52.25 cents per pound. Bid of the Bethlehem Iron Company, 1310 tons, 902,230 = 34.43 cents per pound. These prices would average higher than the present market prices for ingot aluminum bronze, and the work of converting ingot bronze into guns should cost much less than finishing and assembling rough gun-steel forgings.

With regard to a supply of aluminum bronze, it may be of interest to the naval and military public to know that this alloy would probably be, in case of suddenly threatened war, the most available national resource from which to construct high-powered guns. For it would be entirely possible to erect at least two plants within ninety days that would have an output each of at least one hundred and eighty tons per week of aluminum alloy in ingots of the proper grade for cannon. Foundries of sufficient capacity to handle this amount of metal, if indeed there be not such already in the country, could be built in the same time. The turning, rifling, and finishing plants of the larger guns would of course take more time in their erection. As to copper, there is always four or five thousand tons in store in the United States from which to form the base of the alloy. Contrast this picture with that presented by the Gun Foundry Board when it estimated that it would take three years to build the necessary plant to fabricate heavy steel built-up guns, and two years after that to get the first 16-inch guns out.

Before ending this somewhat protracted paper it is desired that attention be called to the remarks of Mr. Wm. Metcalf. Although we disagree with him on the advisability of discussions like this on the gun question, we cannot but thoroughly coincide with him in the hope that these debates will in no way impede the good work of the rebuilding of the Navy and the re arming of our sea coast defenses by adding further confusion to a somewhat confounded subject.

This work of reconstruction as it is now going on is eminently wise and patriotic, and it is a surprise, which I as a citizen take pride in, to witness how much is being done, and well done, at the various navy yards and construction plants by the Army and Navy Departments, when it is considered how little money has been appropriated in the past for this work, and how limited the experience on this side of the water has been in these matters; and any change in the established programme of defense decided on by the proper authorities should come in as additions and reinforcements to the work now under way. To that end every citizen should contribute his influence and help, be it great

or small, until the nation is in a position to defend itself and enforce such respect as is due both to national as well as international law and order.

## ADDENDA.

The following late tests have been made on aluminium bronze, and are given as they bear somewhat upon the discussion:

Bar of $A_1$ metal rolled hot from a two-inch billet down to $\frac{11}{16}$ inch diameter and tested at the Washington Navy Yard.

Tensile strength per square inch of original section, 92,361 pounds.

Tensile strength per square inch of reduced section, 127,755 pounds.

Elastic limit per square inch, 44,299.

Elongation at failure, 28.76 per cent.

Elongation after fracture, 32.74 per cent.

Reduction of area at failure, 27.7 per cent.

Reduction of area after fracture, 38.2.

Dimensions of specimens between measuring points, diameter .561 inch, length 2.85 inches.

Watertown Test No. 4647:

$A_1$ aluminium bronze that rolled to bar one and one-eighth inches in diameter.

Sectional area of test bar, .25 of a square inch.

Gauged length, 6 inches.

Tensile strength, original section, 89,920 to square inch.

Elastic limit, 50,000 to the square inch.

Elastic extension, .0187 or .0031 per unit length.

Modulus of elasticity, 16,551,700 pounds.

Elongation after rupture, 30 per cent.

Contraction of area, 49 7 per cent.

Hardness, 16.9, taken on the metal that had not been elongated and thereby still farther hardened.

The reserve of ductility in this case shows that cold working would still further elevate the elastic limit.

Watertown Test No. 2469:

$A_1$ aluminium bronze hot rolled from a two-inch billet to $\frac{11}{16}$ inch round bar.

Sectional area of test bar, .20 of a square inch.

Gauged length, 2 inches.

Tensile strength, 111,400 pounds per square inch.

The report reads: Probable elastic limit 84,000 pounds per square inch.

Elastic extension, .0191 or .0095 per unit length.

Elongation after rupture, 6.5 per cent.

Contraction of area, 6.9 per cent.

Watertown Test No. 2467:

Determination of hardness of $A_1$ aluminium bronze cast in chill mold.

ness of piece, 21.17.

The following contribution from the distinguished engineer, R. Van Langhenhove, of the University of Liège, Belgium, was received too late to be presented to the meeting, but is here inserted as a valuable addition to the discussion:*

HAREN, BELGIUM, *October* 18, 1887.

TO THE MEMBERS OF THE NAVAL INSTITUTE, ANNAPOLIS, MARYLAND.

*Gentlemen*:—I thank you for the kind attention you have paid me in sending me the remarkable work of Mr. Alfred H. Cowles, of Cleveland, on the employment of aluminium bronze as raw material for the fabrication of heavy guns. I will not permit myself either to deny or confirm most of the facts which he has just submitted to your learned criticism, not having had occasion to study as closely as himself the experiments to which he has devoted himself for nearly two years past. Still, having, during 18 months, followed, at a great distance, with the minutest attention, the development of the process of fusion by electricity invented by Messrs. E. H. and A. H. Cowles, I can, notwithstanding a lack of knowledge in the matter of artillery that I do not seek to deny, bring to the debate the balance of my feeble lights to aid in solving a problem, the solution of which all Governments anxious for their independence and for the integrity of their territory have sought and are still seeking every day—the construction of the most perfect offensive and defensive weapons of war.

Not having time to examine the question as to all its conditions, I am forced to sketch rapidly my impressions.

If we consider, first, the fabrication of weapons of war (and by this term I mean more especially guns), we know that a perfect cannon should be made of a metal having the following qualities:

1st. Great freedom from foreign matter;

2d. Great homogeneity;

3d. A sufficient tenacity, in order that, without requiring huge dimensions, it can resist pressures engendered by the expansion of the gases produced by the explosive mixture;

4th. Great hardness, in order to resist the corroding action of the gas products under the influence of a high temperature, and the destructive action of the projectile passing along the bore of either the rifle-cannon or smooth bore;

5th. Not to burst in a manner dangerous to those serving the piece—a quality which has a great influence on the *morale* of those people;

6th. To be produced in a regular way, so as to give to the constructor a certainty of obtaining the quality which he needs;

7th. To be of a suitable price, for the cost of acquiring the material of war being enormous, it is necessary that gun metal should be of the lowest price possible; and finally,

8th. It is necessary that the raw material for the fabrication of guns should be delivered to the arsenals in quantities equal to the needs.

*Translated by Lieutenant D. H. Mahan, U. S. N.

Let us seek, then, in accordance with this programme, which is the metal that satisfies most completely the qualities therein enumerated. Without entering into the discussion of the comparative values of cannons of wrought iron, cast iron, tin bronze, and steel, we can immediately throw out of consideration wrought-iron cannon, the making of which has been considered in all times absolutely defective, and cannons made of tin bronze, which have been dethroned for many years by those made of phosphor bronze.

Our field of investigation reduces itself, then, to a consideration of cast-iron and steel guns. From the elements of criticism that I possess, it is shown clearly that cast-iron guns suitably made on the system of cooling from the centre of the bore, as for example by Rodman's method, and suitably strengthened by means of bands of iron or steel, have nothing to concede to steel guns made after the most perfect processes; and Mr. Alfred Cowles seems, in confining himself entirely to steel guns simply cast or made of pieces supporting one another,—that which he calls "a built-up gun,"—to neglect too much the modest cast-iron guns, since the length of service of these latter bears honorable comparison with the former.

This is so true that one of our most distinguished steel engineers, Mr. Greiner,* (of whom I shall have occasion to speak later), himself cites, in the following terms, the example of a cast-iron banded gun that was proved at the same time as a steel Krupp gun, and had acted much better: "This cast-iron gun with steel bands has undergone at the depot of Braesschat some comparing proofs with a Krupp cast-steel gun of the same dimensions, and the *results are all in its favor*. Similar trials have already been made in France. In this last country they have for some time adopted, for the large calibres, cast-iron guns rendered more resisting by steel bands placed on hot."

It is not to be denied, however, that cast iron possesses an absolutely insufficient specific resistance. Nevertheless the cast-iron cannon are made of metal in a state of fusion, and consequently the metal of which they are formed possesses as a quality a homogeneity which constitutes its principal merit, and which is as strongly claimed in favor of cast steel.

Metallurgists and artillerymen have naturally been brought to occupy themselves in replacing a metal of feeble tenacity by the, as they say, far more resisting steel; and, thanks to the progress made in its manufacture during the last 30 years, they have procured it for some time past at a reasonable market rate, or, at least, the increase of price has not been made a cause for rejection *a priori* by the artillery board.

As, however, steel is actually the object of the discussion, since it is metal employed for the fabrication of heavy siege or defense pieces, I myself, like the author of the remarkable work which has just be study of the employment of steel and of aluminium bronze for the heavy guns.

And, in the first place, what is steel? If we consult the written and published by our greatest metallurgists or our best cannot get a precise idea of this siderurgistic product. The w

* Director-General of the Cockerill Works at Seraing, Belgium.

could find the opinion of the siderurgists of your great and marvellous country are not familiar to me, so I wish to cite only the opinions of the authors of the European continent, correspondence with whom is habitual to me.

That eminent authority on steel, Mr. A. Greiner, chief of the important establishment of Cockerill, at Seraing (and whose name I have already mentioned), gave in 1872 a definition for steel, to which he referred three years later only to confirm it, in saying, "They give the name of steel to all those *malleable* products of siderurgy obtained in a *state of fusion.*" He preserves the name of iron for all those *malleable products which have not been in a state of fusion*: and he gives as a parallel scale for the classification of irons and steels the following table:

SCALE OF MR. GREINER.

| Series of Irons. | Amount of Carbon. | Series of Steels |
|---|---|---|
| Ordinary irons, | 0 to 0.15 | Extra soft steel. |
| Grained iron, | 0.15 to 0.45 | Soft steel. |
| Steely irons or puddled steel, | 0.45 to 0.55 | Semi-soft steel. |
| Case-hardened iron or steel. Steels of Styria. | 0.55 to 1.5 per cent and over. | Hard steel. |

Therefore, according to Mr. Greiner, irons and steels can have identical chemical compositions, but only differ from one another by the manner in which they have been treated in the kiln.

Before him, the eminent Austrian metallurgist, Mr. Tünner, had given the following scale, which deviates notably from that of Mr. Greiner:

| Number in Classification. | Amount of Carbon. | Qualities. |
|---|---|---|
| No. 1, | 1.50 per cent. | Mixed steel. |
| No. 2, | 1.25 " | |
| No. 3, | 1.00 " | Tool steel. |
| No. 4, | 0.75 " | |
| No. 5, | 0.50 " | Homogeneous metal. |
| No. 6, | 0.25 " | |
| No. 7, | 0.05 " | Cast iron. |

Mr. Greiner finds, then, that iron not containing one atom of carbon is steel if it has been obtained by fusion.

He has, however, obtained from a great number of metallurgists, amongst others Mr. Jordan, the learned French engineer, entire approbation; but, on the other hand, he found in Mr. Grüner, Inspector-General of Mines in France, a declared adversary.

The latter calls steel, "all metal malleable both hot and cold and *capable of being tempered*, intermediary between the soft iron, malleable both hot and cold but not susceptible of being tempered, and cast iron, not malleable but susceptible of being tempered by a sudden cooling."

Before them Mr. Karsten had said: "Steel is a hard metal, ductile, less easily welded than iron, and above all, more fusible as its property of being welded diminishes."

Finally, Mr. Percy says: "The carbon is present in certain proportions; and within limits which cannot be *exactly* fixed, there are these different varieties of steel—very elastic, malleable, ductile, easy to weld and forge, very tenacious, fusible at high temperatures."

To sum up the difference between the opinions of the authorities I have just cited:

*A*. For cast iron and steel. 1. According to Messrs. Karshen and Percy, the malleable and welding qualities. 2. According to Messrs. Greiner and Grüner, malleability.

*B*. For iron and steel. 1. According to Mr. Karshen, the welding and fusing qualities. 2. According to Messrs. Grüner and Percy, the temper. 3. According to Mr. Greiner, the fusion or the melted state.

If, then, it is a metal which complies with such an elasticity of valuation that it is iron even at 0.6 per cent (Percy) of carbon, and that it is steel when it contains none of it, what can we conclude from what precedes, except that it is not a metal, precise, determined, special, but an alloy of iron and carbon? And in fact, from the fusible casting containing six to seven per cent of carbon, up to the iron in a melted state, the scale is so vast that any other definition seems impossible. In fact, no one can state where steel commences or where it ends, although it is certainly known that when it is surcharged with carbon it is no longer steel, but iron. I have said it was an alloy. An alloy it is, in the same category with the alloys of copper, tin, zinc, silicon, aluminium; and according to the proportion more or less great in which it is united with charcoal (I do not say combined), it possesses or takes different properties, just as the combined metals communicate to the copper with which they unite or combine qualities which depend on the percentage of metal added. But if the steel is an alloy of iron and carbon, it is so much the more an alloy of an absolutely unstable nature. When one sees a metal take properties so different, according to the percentage of carbon, that a few hundredths causes it to pass from a soft to a hard state, what confidence can one have in it for the construction of large pieces of artillery (for, gentlemen, it is only with that point in view that I discuss the value of steel), in which the conditions of regularity, of homogeneity, and of security are primordial, absolute, indispensable?

Instead of following, in the employment of steel (in a crude state) for manufacture of cannon, an immutable method and fixed rules, we see t employment of the metal depends upon an opinion more or less sp acco to the views of the operator. It is no longer a law which guides t c it is his good pleasure, it is his personal opinion, more or less reasoned out based on an experience more or less great—in a word, it is fe

And, in fact, what do we ascertain in practice? Let us see, for ex happens at the Arsenal at Woolwich, that universally renowned There private industry finds a free path and furnishes to the state the materials which are used in the manufacture of cannon—and ascertain?

The following tables which Mr. Greiner gives us will enlighten on this subject:

| Origin. | Number of block. | Carbon. | Manganese. |
|---|---|---|---|
| Firth, . . . . . . . | 5592 | 0.338 | 0.075 |
| | 5614 | 0.400 | 0.126 |
| Whitworth, . . . . . | 5607 | 0.300 | 0.312 |
| | 5658 | 0.417 | 0.240 |
| Vickers, . . . . . . | 5761 | 0.240 | 0.216 |
| | 5759 | 0.272 | 0.225 |
| Cammell, . . . . . . | 6067 | 0.143 | 0.341 |
| | 5889 | 0.194 | 0.248 |

**There is the raw material! No rule, no law—a chemical composition eminently variable, its components varying from 0.075 to 0.341 for manganese, and from 0.143 to 0.417 for carbon; and this is the metal which is going to be worked** up to make homogeneous pieces! There is shown in the following table the products obtained:

| Origin. | Natural State. | | | Tempered at Low Temperature. | | | Tempered at High Temperature. | | | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Limit of Elasticity | Breaking Strain. | Elongation | Limit of Elasticity | Breaking Strain | Elongation | Limit of Elasticity | Breaking Strain. | Elongation. | |
| | Pressure in kilograms per square metre | | | Pressure in kilograms per square metre | | | Pressure in kilograms per square metre | | | |
| | per ct. | per ct. | per ct. | per ct. | per ct. | per ct. | per ct. | per ct. | per ct. | |
| Firth.......... | 18.60 | 48.05 | 23.04 | 49.06 | 75.90 | 23.69 | 48.18 | 63.91 | 13.62 | Breech. |
| | 17.05 | 45.57 | 17.27 | 57.24 | 82.99 | 28.77 | 60.48 | 89.17 | 9.59 | Chase. |
| Whitworth...... | 22.41 | 52.16 | 23.54 | 54.22 | 80.92 | 12.53 | 54.69 | 81.00 | 12.48 | Breech. |
| | 22.21 | 50.80 | 23.16 | 54.66 | 80.11 | 11.97 | 54.54 | 80.40 | 12.75 | Chase. |
| Vickers......... | 18.29 | 47.36 | 24.26 | 45.04 | 70.46 | 14.05 | 46.21 | 71.68 | 14.49 | Breech. |
| | 22.53 | 51.79 | 14.09 | 54.95 | 79.15 | 7.07 | 55.39 | 77.28 | 7.16 | Chase. |
| Cammell ...... | 21.54 | 43.99 | 27.20 | 54.92 | 67.72 | 14.05 | 46.04 | 68.94 | 12.70 | Breech. |
| | 18.94 | 41.92 | 28.70 | 50.45 | 72.71 | 12.95 | 53.01 | 75.77 | 11.80 | Chase. |

No fine phrases are needed in drawing a conclusion from the two preceding tables, when we find such very different metals as those furnished by the firm of Cammell, which contain only 0.143 and 0.194 of carbon, comparing in tenacity and elongation after tempering with the steels of Firth, which contain 0.338 and 0.400 of this metalloid. For alongside of this metalloid we see the metal manganese play an important part, strengthening my previous conclusions that steel for cannon is an alloy, and this time not simple but composite, in which silicon, sulphur, and phosphorus play a part alongside of carbon, and in which manganese in its turn intervenes in order radically to defy the theories expressed by the learned engineers whom I have named.

I do not wish to wear out your attention by mercilessly following the action of steel as a metal for guns, but I have said that the steel alloy or cast steel which serves for the construction of pieces of large calibre is an alloy of a nature eminently unstable, and I prove it. It is impossible, in fact, to use this cast metal for an ingot mold or for a mold for the manufacture of cannon of

considerable weight. The enormous masses produced by the casting (tapping) have in themselves a chemical and molecular composition absolutely variable, and this variableness is increased so much the more as the mass is increased.

Steel prepared for the manufacture of cannon should be fine grained. If the fracture shows fine grain the steel is practically of good quality. It possesses then the requisite tenacity, supposing that all the other influences destructive of that tenacity have been eliminated. If the fracture shows coarse grains or crystals the product is defective and the piece of a poor quality.

Now, as an absolute opinion, the irregularity of crystallization cannot be completely overcome during the process of casting very large pieces. It is the forge that is destined to bring about as great a uniformity as possible. Forging, however, whilst approaching that end, does not attain it. In fact, these enormous pieces of steel which after being worked are suitable for constructing cannon, require to be heated to high temperatures for the forging. The more that temperature is raised, the more sensitive the metal is to the action of the gases in the furnace and the more rapidly its chemical composition changes. It loses little by little its carbon and is converted slowly into iron at the surface, whilst the centre remains intact. We have then, at the moment when the ingot is carried to the hammer, a mass at a high temperature whose particles are separated by a distance which depends upon the degree of heat, and which the force of the hammer does not succeed in reducing until the moment when the powerful heat diminishes; so, through the cooling and the uninterrupted hammering, the mass has not time to crystallize, but is found after complete cooling to possess the tenacity and the homogeneity sought for, provided, always, that the chemical combination remain the same throughout the mass.*

But Mr. Jordan says: "The large forged pieces, the plates which several times through the furnace to be reheated and which cool at each heating, are apt to crystallize under the repeated blows of the in the central parts *which the shock does not reach*, and in fact do cry *at the core*. In order to remedy this and prevent ruptures follo cracks, it is necessary, when the piece is completely fashioned, not it to cool to the centre, but to replace it in the furnace until the e hot, after that to bring back the iron by tempering it in water, wa warm for the little pieces but cold for the large pieces like example; *without that precaution* an armor plate of good iron into large pieces under the shock of the ball *instead of res it.*" then, to attain the double end—preventing the molecular m as the chemical modification—is impossible, for the metal periphery to the centre, from the moment of the casting up to the furnace during the forging, owing to the action of the furnace atmospheric air, or to the mode of cooling.

Moreover, the ingot of steel, from its casting to the moment when it to the furnace for refining the metal and warming it for al

* Tchernoff, director of the steel works of Obankoff (St. Petersburg), in a note comm the Imperial Technical Society of Russia.

always and inevitably, scattered through all the mass, an enormous quantity of blisters or cavities filled with cracks, scoriae, or air, which never disappear completely, notwithstanding the energetic hammering under the weight of powerful machines. I stop this statement here, since time forces me to keep within narrow limits, and in order not to vex the staunch defenders of steel "metal." I will admit that steel is in fact a very elastic, malleable, and ductile alloy, easy to weld and to forge, very tenacious, and fusible at high temperatures; but this is only the case when one works carefully on ingots of particular dimensions (generally small), when they are made of a pure homogeneous metal, free from flaws, cavities or cracks, and of a fine regular grain, and when forged and hammered thoroughly in such manner as to preserve at the surface as well as at the core a regular chemical composition and molecular disposition.

But if heavy masses are worked, the finished product will only be an uncertain object, the uncertainty arising (1) from the difference between the chemical composition and the molecular cohesion of its parts; (2) from material irregularities arising from a work that can never be brought to perfection; (3) from differences in the tenacity of the metal, arising from variations produced by tempering; (4) from the impossibility of working up an exact, homogeneous metal, free from cavities and flaws.

My conviction, based on the study of the physical properties of the metal itself, is considerably fortified if we pursue our examination by the study of the manufactured object,—produced by means of the systems so much in vogue a short time ago, but upon which the opinion of men of science is now reversed,—called Krupp guns, Armstrong guns, etc.

Mr. A. Cowles has demonstrated to you, simply but clearly, the inconveniences arising from the manufacture of built-up pieces. This demonstration is sufficient to convince the most incredulous, and he might have ended by saying, with one of your distinguished compatriots, Mr. W. Metcalf, of Pittsburg, that when the cannon fashioned after the system called "built up" is finished, "*it is only a mass without scientific or mechanical value, and of a resistance absolutely uncertain.*"

I do not wish, before an assembly so competent as yours, to re-open the chapter of accidents and disasters published in the newspapers (as I write I learn that the large cannon of the de Bange system which has figured at the Universal Exposition at Antwerp has just burst), and enumerate the dreadful but too numerous disasters which have occasioned the death of so many intelligent and brave officers and unfortunate soldiers—without counting the losses of material—the number of which suffices to prove the necessity of removing from the field of battle, both on land and sea, these engines which seem to be as fatal to those who manage them as to those against whom they are turned.

Neither will I dwell on the enormous cost of manufacturing these pieces, a cost occasioned entirely by the unstable, unknown, and puzzling nature of this metal which no one can master, and in the handling of which one cannot take too much care; which requires expenditure of much money and time, the employment of the largest and most accurate tools, and makes necessary a large plant, great space, and considerable capital to bring it within determined limits, limits that are attained only by a mere chance.

In fine, to wish to produce a metal which, in a suitable state of purity and finish, ought regularly to sustain a resistance of from 10 to 12,000 kilograms (9 to 11 tons) per square centimetre, but which, after having been confided to the most clever and experienced workmen, after having received the greatest care, after having been heated in furnaces built with all the science of the engineer, and after having been compressed under trip hammers of 50, 80, and 100 tons, only gives a resistance of from 3 to 4000 kilos per square centimetre, and will often burst at the first firing—this is no longer progress, it is retrograding: it is no longer science, it is blindness!

In conclusion, I say that a metal of a natural resistance of 10 to 13,000 kilograms per square centimetre, which only gives, after the considerable manipulations to which it has been submitted and which increase its value twenty times, a result three times less than the maximum, is a metal that ought to be condemned.

I will only say a word on the subject of aluminium bronze as a metal destined to replace steel and cast iron in the construction of all pieces of artillery, from the smallest to the largest.

Do not believe, gentlemen, that the statement of the advantages of aluminium bronze which has just been shown to you with so great moderation by Mr. Alfred Cowles, is of a recent date, and is caused only by the introduction on the metallic markets of numerous and remarkable alloys due to the invention of the reduction of minerals by the electric furnace. This application of aluminium bronze was predicted long ago by Mr. Weber, Colonel of Artillery, director of the Royal Foundry at Augsburg, Germany, soon after the happy invention of the process by Mr. St. Clair Deville.

In 1859, [illegible] years ago, Colonel Weber stated that aluminium bronze resisted [illegible] kilograms per cubic centimetre), whilst tin-bronze cannon did not resist more than a pressure of 2784 kilograms (per cubic centimetre) [illegible] great care and extraordinarily minute work.

[illegible] a comparative estimate of the cost of [illegible] and tin bronze, and notwithstanding that the [illegible] was then [illegible] francs for 100 kilograms (2000 dollars for 220 pounds), he found for the first a price of 1378 francs for 100 kilograms, and for the second [illegible] francs only. Notwithstanding this difference in price [illegible] the employment of aluminium bronze cannon. To-day the [illegible] Company sells on the market for about 450 francs per [illegible] one-third the price it was thirty years ago.

[illegible] should then be realized with more certainty [illegible] lower price and greater abundance [illegible] war, the metal, prepared without the [illegible] the process of St. Clair Deville, proceed- [illegible] with first class copper, should resist,—and [illegible] resist,—much greater strains than at that time.

[illegible] of aluminium bronze, but we know [illegible] it possesses, with what marvel-

lous facility it invariably casts, that it is exempt from cavities and flaws, and possesses an astonishing homogeneity and regularity of composition. Its chemical composition and molecular disposition do not vary throughout the mass. Its low point of fusion permits it to escape treatment under the influence of high temperatures, thus removing one of the disadvantages so disastrous to steel. But it can be asserted that, strong, resisting, homogeneous, compact, regular as is aluminium bronze, it will be possible to reduce the weights of metal considerably in working it, to obtain equal results. For there is no use dissimulating; in order to produce steel cannon of determinate power, it is practically necessary to give it a much greater weight than that absolutely required—and yet we know the result arrived at.

It is not necessary to take such precautions with aluminium bronze. And likewise, the dimensions of pieces made of a metal regularly obtained can be exactly calculated, and they can be constructed without giving more weight to them than the coefficient of safety indicates; at the same time a cannon in aluminium bronze can be made of much smaller dimensions whilst obtaining the same result. Consequently, the comparison between the prices of steel and aluminium bronze, such as has been furnished to you by Mr. Alfred Cowles, will increase notably in practice.

I regret that time is wanting to give to this interesting subject the development that it deserves. But I close, gentlemen, by thanking you for your kindly attention, and I doubt not that the issue of the discussion to which you apply yourselves to-day will be favorable to the new practical metal which the marvellous invention of the Messrs. Cowles has called to the attention of the intelligent world.

R. Van Langhenhove,
*Engineer of the School of Mines, Arts, and Manufactures, annexed to the University of Liège.*

The following letter bearing upon this discussion was forwarded by Mr. Cowles, and is here published with the consent of the writer:

Rose Polytechnic Institute,
Terre Haute, Ind., *November* 3, 1887.

*My dear Mr. Cowles:*—I have hoped to find time to answer your letter earlier and at greater length, but a press of other occupations has prevented. I read your paper on aluminum bronze with great interest, as I have watched with great interest your development of the process of its manufacture. I am and have been convinced that you have done a good thing, good for others, and I hope it will prove to be good for yourself. As far as I can see, your arguments in the paper are sound, and I think you have made a very strong case.

I think there can be no question that there is greater danger from "explosive bursting" where there is a lack of continuity in the structure of the material, as in "made-up" guns, than where continuity exists, even if homogeneity does not, other things being equal. While reading your paper I could not but think of an illustration of this, drawn from a subject to which I have given a

good deal of thought for several years. I refer to the destructive effect of earthquakes. Whenever an earthquake wave strikes a structure which is *lacking in continuity*, as a building of brick or stone, or both, the destruction is much greater than it is where the parts of the structure are so framed together as to make them practically one. The latter form is often seen in a well framed Japanese house, in which the timbers are *pinned* together, so that the building vibrates as an elastic whole. In a "made-up" gun the effective strength must often be only that of a single band or cylinder, unless the greatest precision is used in its construction. The reflection backward of a wave at a surface of separation is an established fact in physics, and I see nothing unreasonable in your hypothesis that to this may be due, in some degree, the rapid crystallization of the material. I think you can "defend" your thesis with good reason, and I have no doubt you will succeed in so doing. If not too much trouble, I would be glad to receive a few specimens of your bronze—for our cabinet—and to be referred to the best published description of its preparation.

I hope to hear of any improvements which you are making, and beg leave to subscribe myself, Yours faithfully,

T. C. MENDENHALL.

Mr. Alfred H. Cowles, Lockport, N. Y.

## NOTICE.

It is proposed to continue the discussion of Aluminum Bronze for Heavy Guns in the early part of February next at the Newport Branch, at which time the Cowles Brothers expect to be prepared to present additional proof of the suitability of their alloy for gun-metal. The exact date of the meeting will be announced later in the service journals and by circular letter.

Those desiring further information in regard to the meeting will please address Prof. C. E. Munroe, Corresponding Secretary, U. S. N. I., Torpedo Station, Newport, R. I.

CHAS. R. MILES, *Lieut., U. S. N.,*
*Secretary and Treasurer.*

# PROFESSIONAL NOTES.

## OUR COAST DEFENSE, ITS COST, AND ITS MECHANICAL PROBLEMS.

(A Review.)

A paper by Joseph Morgan, Jr., with the foregoing title, and the discussion of the same published in the current volume of the *Transactions of the American Society of Mechanical Engineers*, contains so much of interest to the members of the Institute as to deserve more than a passing notice. Mr. Morgan, in consequence of his investigations as one of the civilian members of the Fortification Board, has fully equipped himself for an intelligent treatment of the subject in hand; and he deserves much credit for bringing the mechanical problems of defending our coast to the attention of such a progressive and influential body as the American Society of Mechanical Engineers. We believe it is by continually presenting the subject in this way, and thus arousing a strong public sentiment against the present unwise abandonment of our sea-coast to the possible ravages of an enemy, that Congress may be brought at no distant day to grant liberal appropriations for the national defense.

In the introduction to his paper Mr Morgan says: "This paper is intended to open a discussion on coast defense, and to call attention to important facts which should be familiar to every one, or about which there appears to be misinformation." He then proceeds to the consideration of the cost of putting the coast in a proper state of defense. In this connection he says that the cost as estimated by the Fortification Board, for 27 ports, was $126,377,800, to be expended at the rate of $11,000,000 annually for a period of 12 years, this being at the rate of about $2.52 per head, reckoning the population of the country at 50,000,000. This, he estimates, "is barely 2 per cent of the value of the destructible property of these cities, or about the premium paid for ordinary fire insurance on a good risk for a three years' policy."

Mr. Morgan, in answer to the question, "Why should our defenses remain obsolete?" says: "Apply to this question the judgment which a manufacturing concerns applies to its business. Would a management with good sense neglect to put in new plant, and allow its factories to remain filled with machinery of capacity unequal to competition with other plants springing up around it? Such a concern would soon go out of business. We should have defenses complete with all preparations necessary to defend our shores from any force, land or naval, which may be brought against us. Proper means being provided, we would be able at short notice to beat off an enemy with little cost to ourselves, with great damage to him, and small chance of success on his part."

It will be well here to insert from Mr. Morgan's paper a few extracts that bear particularly upon the naval part of the defense of the coast:

"It is perfectly feasible to day to land a force on our shores. It would, however, be impossible to maintain such a force, except in close communication with some convenient port occupied as a base of supplies. To prevent such occupation and the levying tribute upon our great coast cities is the object of our coast defense, or, to quote Bernard and Totten's report, 1826:

"'Fortifications must, 1st. Close all important harbors against an enemy and secure them to our military and commercial marine.

"'2d. Deprive an enemy of all strong positions where, protected by naval superiority, he may fix permanent quarters in our territory, maintain himself during the war, and keep the whole frontier in perpetual alarm.

"'3d. Cover the great cities from attack.

"'4th. Prevent, as far as practicable, the great avenues of interior navigation from being blockaded at their entrance into the ocean.

"'5th. Cover the coastwise and interior navigation by closing the harbors and the several inlets from the sea which intersect the lines of communication, and thereby further aid the Navy in protecting the navigation of the country.

"'6th. Protect the great naval establishments.'

"It is taken for granted the proper line of impregnable defense is not an off-shore fleet. Although a naval officer is quoted as saying, 'We need no forts, but our coast defense should be intrusted to a navy,' his position is erroneous. A navy to protect our extended shore of over 4000 miles, and ready to meet a squadron of the enemy anywhere on the coast, means a powerful fleet at many points, and involves an outlay immensely greater than coast fortifications. To meet a possibly superior naval force and join it in battle with no alternatives but victory or destruction afloat, followed by surrender ashore, is not the task to be given to our naval force.

"'The Navy should be free to seek the high seas,' to accept the issue of battle when victory is possible, to destroy commerce of the enemy, to harass the flanks of a superior force, cut off its supplies, and, when close pressed, find, under powerful guns ashore, an efficient shelter. It should be a flying column, not tied to a harbor defense line, but free to go even to the enemy's own shores and thus keep his fleet at home. It should be powerful enough, when concentrated, to break up a blockade of our important ports.

"To permit this concentration of the naval force, the defense of any port must be complete without a navy. A navy may assist, although it should not be essential to the defense. It can follow up crippled vessels, destroy them after repulse by fortifications, and make defeat in attack a total ruin to the enemy.

"The defense of harbor entrances by guns afloat, exposed to destruction from shot and torpedoes, and mounted upon the most costly, complicated and delicate of gun carriages, a steamship, is an expedient only to be adopted when other locations for the guns are not available.

"This is not the age of chivalry, when one offers an enemy equal terms of battle, but the age of science and mechanism, when results are calculated, and we offer an adversary destruction if he accepts battle on our prepared ground. The defense, therefore, should be, when practicable, at the harbor mouth, by permanent works. To be complete and impregnable, there must be obstructions in the channel, to prevent a run by, and powerful guns ashore to keep the enemy's fleet from removing the obstructions or quietly anchoring and bombarding cities near the shore without danger to themselves. There must be obstructions because 'modern ships of war with high speed and heavy armor can pass any shore battery if the channel be clear.' There must be guns, otherwise the enemy will destroy the torpedo obstructions by countermining. The guns must be heavy, for while light guns would prevent countermining by unarmored vessels, the heavy armored vessels would proceed with this work, unless prevented by armor-piercing guns on shore. . . .

"For flanking guns to prevent unarmored vessels and small boats fishing up or countermining torpedo obstructions, our present forts with present guns and a few machine guns will answer. A fleet of harbor torpedo boats should also be available to assist in making the torpedo defense dangerous, should the enemy, at night or in fogs, attempt countermining or removal of torpedoes. The boats would also make blockades dangerous, or compel the enemy's squadron to haul off coast at night. They may be, say, boats of 100 feet length; [illegible] knots per hour. There should be enough of them built at once to

train our engine and boat builders, to bring the special knowledge required, and to have the plans and details well developed. Then, in case of necessity, these small engines could be turned out in numbers from our numerous shops, trained to do good high-speed engine work, and the hulls could be built anywhere and transported by rail or canals to our lakes and harbors. The Fortification Board recommended the building of about 160 of these torpedo boats, to be distributed to various ports; New York, San Francisco, Boston, Hampton Roads, New London, Portland, Oregon, to have 18 each; New Orleans, 12; Philadelphia, Portland, Maine, Narragansett Bay, Key West, and Charleston, 6 each; and lake ports, 12 torpedo gunboats.

"Another item in the scheme of coast defense is floating batteries, for which five ships, three at San Francisco and two at New Orleans, are estimated at a cost of $19,000,000. At San Francisco the depth of entrance and strength of currents prevent the use of torpedoes. At New Orleans, near the heads of passes where torpedoes must be, no foundation can be had for heavy gun protection on shore. The vessels designed for this are superior in armor protection and offensive power of guns to any now afloat.

"The report of Commander Sampson, United States Navy, of Fortification Board, upon the proper use of navy and floating batteries, is a very interesting and able one. Of the whole $126,000,000, however, estimated as necessary to defense, over $94,000,000 are for forts and for armament of heavy guns." . . .

In regard to the view thus presented by Mr. Morgan respecting the part to be taken by the Navy in the defense of the coast, Lieutenant-Commander F. M. Barber, U. S. N., in his discussion of the paper, makes the following timely criticism:

"I am aware that this view is thoroughly indorsed by the report of the Fortification Board, of which he [Mr. Morgan] was a member, and I would not like to be understood as undervaluing the recommendations of the Board in so far as the kind of defense they recommend is concerned; but, in regard to the quantity of floating defenses and the part that must necessarily be taken by the Navy, their position is not a strong one. I am particularly anxious that I should be correctly understood in this matter, for I well understand the evil effect of officers criticising each other's reports where the appropriation of money is involved, as it confuses the public. Nothing that I have to say would alter the specific use of a dollar from the purpose for which the Fortification Boar would apply it. They have recommended none too many defenses at anchor; but they have not protected those at anchor with enough that move. 'The Navy should be free to seek the high seas,' as the paper says; but its freedom to do so should depend upon the fact that it has enough ironclads and torpedo boats (surface and submarine), with officers and men to man them, still remaining to do their share in protecting the coast. In these days of torpedo warfare, I take the broad ground that the defense of no port can be complete without the Navy. Not only it *may* assist, as the paper suggests, but it *must* assist, and it is absolutely essential to the defense. No coast can be properly defended, according to the ideas which I believe are most prevalent in Europe, without an outer line of ironclads, an inner one of gunboats and torpedo boats, and lastly, the fixed defenses at the bottom of the harbor and on the shore. The officers and men of the Navy have unquestionably the particular kind of education which adapts them to the two lines afloat, and torpedoes fixed and movable have caused such a gradual crawling down of all the live defenses of a port, off the land and into the water, that more and more aquatic knowledge is necessary, and in Europe this whole matter is gradually drifting bodily into the Navy, forts and all. In Germany it is already done. In France, coast defenses are in an amphibious state, and in England, judging from the discussion of the paper of Colonel Schaw, of the Royal Engineers (Deputy Director of Fortifications), read before the Royal United Service Institution in December last, the necessity of some kind of combination of the Army and Navy is recognized and its consummation is probably a matter of the near

future in England. One of our most prominent army torpedo experts once told me that he could see plainly the desirability of some such arrangement in order to obtain a more perfect knowledge of the value of fixed mines with reference to their location. Said he, 'I know what *I* think a navy-man would do if he had to attack any harbor; but I would very much like to know what *he* thinks he would do.'

"As Viollet le Duc argues in his *Annals of a Fortress*, 'the proper place for defense is at the outworks, to harass, discourage, and demoralize your enemy, and prevent work on his system of approaches.' But this only enhances the value and necessity of a stronghold which you know is always in your rear, and to which you can retreat from time to time, but which could scarcely be made so formidable that a modern fleet could not pass it eventually, if the approaches were once clear and could be kept so. Guns and electric lights on shore would not sufficiently protect the submarine mines at the bottom of the harbor. Co-operations of army and navy will probably be the solution of this problem in our country, and the horse marine will become a living actuality.

"The Fortification Board recommended but 160 torpedo boats for our enormous stretch of coast (it is 12,000 miles instead of 4000, if we include the lakes and Alaska), while Germany is building to-day 150 torpedo boats for her exceedingly limited coast line. The Board recommends but five armorclads, three for San Francisco and two for New Orleans. It is true, as the paper says, that they are the most expensive gun carriages in the world; but they are movable, and while the Board provides fixed protection for the principal ports on our coast, it makes scarcely any provision for the coast between the ports. To fortify strongly only important places is an open invitation to an active enemy to effect a landing at the unimportant ones, and it should be remembered that, unlike Europe, we have no inland fortifications whatever in our country. Cost what they may, movable defenses must be had, and their power of concentration on any point attacked renders them far cheaper than a continuous line of strong fixed defenses.

"The following information, from reliable sources, shows the growing importance of the navies of Europe in connection with the problem of coast defenses.

"GERMANY.—The sea-coast defenses, torpedo boats, torpedoes, submarine mines, etc., of Germany, have been placed in charge of the Navy. The Navy Budgets of 1885–86 provide for the expenses of maintaining torpedoes, torpedo boats, and submarine mines, and of the necessary personnel to manipulate them.

"The fortifications have recently been transferred from the Army to Navy, and the following reasons have been assigned for this transfer:

"The forts at the mouth of the Elbe, in addition to those at K Wilhelmhaven, have been transferred to the Navy, and are garrisoned — third battalion of Marine Artillery, which has been added to force for this purpose. These battalions are officered by line Navy, and the non-commissioned officers are seamen-gunners. of the privates are gunners from the Navy, and the rest come fr district in the neighborhood. The change was made on the of the Minister of War, approved by the General Staff and b the Emperor, for the following reasons:

"First. Because the guns and carriages are similar to those Navy.

"Second. As this defense is chiefly against attacks fr landing parties, seamen would more readily appreciate the objects of manœuvres by the movement of the ships, probable designs of the enemy from the preparations.

"Third. That, as the defenses were considerably ma by steam or hydraulic power, a class of men bec lation of the machinery which did not exist in the

"Fourth. That seamen are better adapted to

mouth of rivers, and would co-operate with submarine defenses more advantageously.

"Submarine defenses of all kinds have been placed entirely in the hands of the Navy. They formerly belonged to the Engineer Corps of the Army, but were transferred to the Navy for similar reasons to those given for the transfer of the coast defenses.

"An Imperial order of March 16, 1886, prescribes the duties of the Board of Inspection for Torpedo Affairs of the German Navy; and all defenses of ports and harbors are to be arranged with the approval of the Chief of the Admiralty.

"The submarine coast defense, as organized by the German Admiralty, distributes the available torpedo boats to different districts on the German coast; each district has a torpedo depot, and the amount of torpedo armament of each district depends on the extent, importance, and vulnerability of the district to be defended. The last fortifications remaining in charge of the Army were the forts at the mouth of the Weser, and, by the Imperial order of November 25, 1886, these were transferred to the Navy on April 1, 1887.

"FRANCE.—On the 6th of March, 1886, a ministerial decree created an additional department in the Ministry of Marine, called the Direction (Bureau) of Submarine Defense. This Direction has control of all torpedoes, mines, and apparatus used in connection with them, and all torpedo boats. The Director of Submarine Defense is a rear-admiral, and the service in each port is divided into two sections: 1st. The *défense mobile*, consisting of all torpedo boats and torpedo store-ships; 2d. The *défense fixé*, having in charge all submarine mines, electric search lights and torpedoes operated from the shore, harbor boats carrying spar torpedoes, care of material, mine boats, etc. The commandant of the *défense mobile* in each fort is a commander in the Navy; that of the *défense fixé* is either a commander or lieutenant in the Navy. A French 'Fortification Board,' organized in December, 1886, consists of five naval officers and five army officers.

"ENGLAND.—In England the fortifications and submarine mine defenses are under the control of the Army. The torpedo boats are all under naval control. The question of turning over the command of the sea-coast fortresses to the Navy, and making the latter completely responsible for the defense of the coast, is under the very serious consideration of the British authorities, and the matter is now being discussed between the War Office and Admiralty. It is proposed by the former that the latter shall have entire control, it having come to the German and French view of the subject of coast defense.

"ITALY.—The Direction General of Artillery and Torpedoes of the Ministry of Marine (chief a rear-admiral), in addition to the manufacture and purchase of material, is also charged with the submarine defense of the coast. The Navy is exclusively charged with all that relates to the naval and submarine features of coast defense, including light batteries of guns which may be erected to command lines of fixed torpedoes and prevent the operations of the boats of the enemy, and the surveillance of the coast and its electric lighting for military purposes.

"The general plans of coast defense are studied and drawn up by a mixed commission of army and navy officers. In the projected scheme of coast defense it is intended to assign from three to eighteen torpedo boats to each of the ports of importance, twelve to fifteen in number. Palermo and Naples will be dependent on the fleet for defense, as they can be bombarded from the open sea (so can New York). The general staff, whose chief is the President of the Superior Council of the Ministry of Marine, forms a separate bureau, without administrative functions. It is charged with the study of all that relates to the organization of the maritime forces, the plans of campaign, the defense of the coast, and questions of naval tactics and strategy.

"It is proposed to organize a special corps for coast defense, to be officered by the older men of the several grades of the line officers of the Navy; men

whose age entitles them to be withdrawn from active service at sea, and who, for the same reason, can best be spared. The corps will have all or a part of the coast defense batteries.

"This project is advocated for two reasons: first, to enlarge the sphere of the Navy in the defense of the coast; second, to stimulate promotion. In the event of its creation, the corps of the coast defense will be charged with the duties of the maritime conscription for recruiting the Navy.

"It is also proposed to form a naval reserve of men under forty years of age, to take part in the coast defense."

Mr. Morgan's views in regard to our present system of gun construction are familiar to our readers through the part taken by him in the discussion of Mr. Dorsey's paper, "Steel for Heavy Guns," published in Whole No. 40 of our Proceedings. But as he has perhaps thrown further light upon the question in his present treatment of the subject, a few extracts will be here quoted:

"Of the various details of defense, none have been the cause of so much debate as the construction of the guns and the material of which they shall be made. The Congress committeeman has the lobbyist always with him, and the steel-casting Rodman advocates, the cast-iron gun contractors, the patent gun inventors, and other interested parties have been sufficiently numerous and active to counteract the wisest counsels of our ordnance officers, so that to-day all work upon army ordnance is at a standstill.

"There are symptoms, however, that the cast-iron men are getting tired, and we shall hereafter hear little of the possibility of making a large, high-powered rifle gun of cast iron. The great 12-inch cast-iron rifle at Sandy Hook is practically *hors de combat*, from erosion of the barrel, although only about one hundred and forty rounds have been fired from it. With 54 tons weight it has only the same muzzle energy as a 10½-inch steel gun of 32 tons weight. . . .

"If guns or gun steel can be made equal to the present specification by casting, let them be accepted, but the standard must not be lowered to reach material of a lower grade; nor can casting makers ask the Government to demand higher qualities for forging than for casting.

"No American engineers can put themselves on record as asking for material of low ductility to be put in guns. The engineering work of this country has never been done on a lower standard of excellence than that of the English, French, or German engineers. The makers of steel castings have, so far, failed to make the quality of steel found in forgings, and the task is, apparently, hopeless. . . .

"The question whether we should forge or cast gun material can be left to the commercial test of cost of manufacture, with every chance that the forge will live and grow fat, whilst the foundry will die of starvation. . . .

"The beneficial effect of mechanical work upon a cast steel ingot, in making it higher in elastic limit, higher in ultimate strength, and much more ductile, cannot be denied. This improvement in quality has not yet been obtained with certainty in any other way than by forging. Of a dozen of steel-casting makers doing a commercial business in this country to-day, I do not believe one will undertake to produce a breech gun tube unforged, of quality equal to United States ordnance specification. They will say the ductility and elongation [illegible] necessary in gun material. If this be so, then raise the point [illegible] the elastic limit, and so increase the efficiency of a given weight of gun [illegible] ductile. There is no place for inferior metal in gun construction. The best that can be had is always the cheapest. The steel-castings [illegible] make guns much cheaper by casting than by forging. [illegible] It will hereafter be shown in this country, as has already been proved abroad, that the cheapest way to produce gun material is [illegible] possible shape. Meanwhile, the armament [illegible] while steel-casting enthusiasts search for a [illegible] way [illegible] 'No thoroughfare' has already been written."

We [illegible] Mr. Morgan's remarks on the subject of armor:

"The question of armor also opens a wide field for debate. Shall it be soft wrought iron, iron and steel compounded, all steel, or chilled cast iron? If a forged material is adopted, the reasons for preferring steel are:

"1st. From the small number of times the material is worked, it is certain steel will be cheaper to manufacture than piled wrought-iron material, which taken from the muck bar, cannot be properly massed together with less than five or six reheatings and weldings.

"2d. There are great possibilities of improvement in the manufacture of steel armor, which has so far only been made for a few years and by one concern, and there is reason to hope, with experience of many concerns and a longer time applied to the manufacture, there will be great improvement in its quality. That there can be much improvement in that of wrought-iron armor seems improbable.

"3d. That it is likely soft and hard steels can be compounded in the same plate successfully, which so far has not been done.

"4th. That steel armor, as now made, is at least equal to iron and steel compounded.

"At the time the report of the Fortification Board was made, a trial of chilled cast-iron armor with very heavy guns had not been made, but the trials of Gruson chilled armor at Spezzia, about a year ago, was an event of the greatest interest to the military engineer. A plate of 87 tons weight and 3 to 4 feet thick was subjected to 4 point-blank shots of the 100-ton 17 inch gun with 826 pounds powder, and projectile of 2205 pounds, striking velocity 1765 feet, and energy 47,500 foot tons. The angle of incidence of projectiles was about 40°. The shots were broken up into small fragments. Any one of the shots would have pierced 31 inches of wrought-iron plate; the fourth heavy shot struck nearly in the same place as the second. The plate was, of course, somewhat cracked, but small pieces only having dropped off from the interior, it was considered to have passed the test condition, which was that no fragment should be detached from inside by blow of shot. Full description of the trial is found in the London *Engineer*. The Krupp steel shot that were fired on this trial are said to be equal to perforation of steel plates of 1¼ to 1½ calibres without deformation. These experiments settle the possibility of defending guns in casemates and turrets with a material much cheaper than forged iron or steel. The influence of mass is so great in constructions to resist large shot that a future seems opened for the use of chilled armor for land defenses. And to it I commend the attention of cast-iron gun foundrymen, whose plant the steel guns have rendered useless. Sixty-eight thousand tons of casting will keep them busy and leave the gun forges a fraction of work also."

Mr. Morgan's entire paper and the discussions that follow, by Lieutenant-Commander Barber, U. S. N., Captain Rogers Birnie, Jr., U. S. A., Mr. Oberlin Smith, and Lieutenant Beehler, U. S. N., form a valuable addition to the literature of military and naval science, and we recommend their careful perusal, not only by the mechanical engineers of the country, for whom the paper was specially written and discussed, but by all naval and military men interested in the subject of our coast defense.

C. R. M.

## SPECIAL INTELLIGENCE REPORT ON THE PROGRESS OF THE WORK ON THE PANAMA CANAL DURING THE YEAR 1885.

By Lieutenant W. W. Kimball, U. S. N., assisted by Naval Cadet W. L. Capps, U. S. N.

After giving in detail the work done on the different sections of the canal during the year, the writer concludes with some general remarks, from which we quote:

"This report and previous ones show that a considerable plant is on hand, but it impressed me as being neither large enough as regards grand material, nor of the right kind. The machine shops appeared to be of sufficient capacity for the needs of the enterprise, conveniently arranged and economically constructed. The American dredges are excellent for the work expected of them, yet too few in number, since they could be used in many places where they are not applied. The Scotch dredges, too, are good machines, and the steam clapets all that could be expected, but, like the American dredges, too few in number. In the matter of excavators it would seem that the French chain-of-buckets machines are too light, great complaint being made of them for that reason. The Company is now receiving and setting up much heavier ones, weighing 60 tons each. When working in soft earth, free from stones and roots, there is no doubt that the chain-of-buckets machines have a greater capacity than those of the steam-shovel, American type; but these perfect conditions are often not to be had, and, consequently, some of the contractors prefer the American machines, although their possible capacity is less. The chain of buckets will be stopped by a small stone caught by the lip of a bucket, while the American steam-shovel will work uninterruptedly in stony ground and roots. The Company has withdrawn most of the American machines and substituted French ones. Apart from the fact that the American Osgood and McMaughten & Otis machines can work in more difficult soil than can the French excavators, some contractors prefer them because they do not require a line of rails the length of the cut to be in place before they can begin work, as they, placed on a short section of railroad, can use their shovels the full length of the handle without moving; in other words, they can cut 30 feet ahead, and the same distance to the side, straight into a bank, while the bucket machines must move to and fro along the cut they are making on a road laid beforehand—a three-rail road for the Everads, which dig below the level on which they stand. It is not always convenient to lay the double line of rails necessary for the spoils trains and the excavator, when one of these lines can be avoided by using an American machine. The 5-foot gauge of the Panama Railroad has been adopted for all the dump-lines along the canal, the rails being 30 kilograms, with a very high web. As it is necessary to use the Panama Railroad for transportation, it is of course convenient to run cars from either terminus of the road to any point on the company's switches or dump-lines, but it seems to me it would have been much more economical to have adopted a narrow gauge and to have laid a third rail over the Panama Railroad bed for transportation purposes. The advantage of a narrow gauge on the dumps, where sharp curves and stiff grades must be encountered, is apparent. This was illustrated on many curves, where the high-web rails had to be braced up by iron clips on every sleeper to counteract the tendency to capsize. The dump-cars in use are of the ordinary type and sufficiently good for the purpose; but the Belgian, box six wheel, and the Rogers drivers and bogey locomotives do not seem so well fitted for work in the dump as good saddle-back machines, since these first mentioned require such easy curves in order to haul economically.

The steam cranes for lifting rock seem to work well, but they are
so extensively as one would expect. Great quantities of small mat
Decauville cars and rails, are in use even when it would seem
material could be applied, and I was told that much Decauville work
done, because the contractors could not procure large material by
on the company. In many cases I think the small material was use
the contractors did not care to pay the prices for the skilled
for the work with the large. For clearing the ground and do
work Decauvilles are admirable, but I was astonished to see them
used for removing the spoils on work that had been in hand two y
shown in some of the photographs accompanying this report.
explanation I could find was that the hand drilling and

generally applied in rock work would naturally be attended by small material and hand work.

But few steam drills are used, the holes being pierced in most cases, even in long faces, by long hand drills used without sledges. Of course for such work the headings are low.

I have never comprehended why an outer harbor and inner basin should be dredged at enormous expense, when for one-quarter the cost a breakwater could be built from the lighthouse reef, and if necessary, another from Point Toro, which would make a perfect harbor of all Limon Bay. Wharfage on the terre-plein quay cannot be cited as a reason, since but little wharfage will be needed after the canal is open, and that little can be much more conveniently and economically supplied by piers like those at present in use at Aspinwall; and assuredly such wharfage would answer all purposes for landing construction material. Three or four long piers like those in use by the steamer companies would have been of the greatest value to the canal company in saving demurrage on vessels consigned to it while the terre-plein was being built, where even now the wharf room is insignificant. If the proposed stone quay were built, it would not answer the purpose required as well as piers. Limon Bay properly breakwatered would be a much more commodious and every way more convenient harbor than the dredged basin can ever be. The need of the Corozal basin is apparent. The section of the deflection of the upper Chagres near Gatun is 35 m. x 5 m., and the fall is only 1 m. in 7 k., giving a flow of between 1 m. and 2 m. per second. Now, as this section with the greatest flow passes only 350 mc. per second, and as the barrage tunnel will discharge 400 mc. per second, to which must be added the discharges of the Frijoles and Gatuncillo rivers, and a certain quantity for watershed, it would seem as if the section of the deflection would have to be increased. This is a mere detail, however, and there may be an intention to increase the section in accordance with needs developed. The only other point in the plan that seems to me impracticable is the placing of the canal, the deflection of the Rio Grande and the Panama Railroad, in the narrow valley between Culebra and the Cerro Coyo, where the substratum of slipping clay is found, and where the river must be so near to and so much above the canal, with the railroad so close to the river. I cannot understand what will prevent the deflection and railroad from sliding into the canal when it is dug, and it would seem that these would have to be carried through the hills to the right, if the river cannot be turned into the canal. The large basins between Corozal and Panama are only indicated, and are not really contemplated as a part of the plan.

The methods of work have been indicated more or less in detail in the reports of sections, but from a broader point of view, in regarding the work as a whole, a few other points demand consideration.

The general method, with some notable exceptions, as for example the dredging in the low ground at Colon and Gatun, has been to reduce the higher levels in the canal, dumping the spoils where most convenient, but oftener into the bed of the Chagres, and leaving the barrage and deflections of the upper Chagres for the future. The dumps have been placed 50 m. outside the canal banks, but in many places the slopes of the hillsides are such that there must be a considerable wash-down into the canal. Where the dumps are in the river, the current, of course, takes down a considerable quantity of spoils, which is to some degree deposited in the dredged portion of the canal, and which will have to be dredged out again. This operation will have to go on till the river is controlled and turned out of its course, and to me it seems singular that more work has not been concentrated on the deflection of the upper Chagres, so as to turn the river from its course as soon as possible. The deflection being cut, the dumps from the works in the canal could be utilized for building the numerous embankments in the bed of the river, none of which have been begun, and all of which, as regards the upper Chagres, must be in place before the river is controlled. This much accomplished, the river bed not needed

for deflection section could be used for dumping into without the possibility of there being any trouble from deposit in the canal. The longer this question is left unsettled, the greater will be the damage done by floods. It is true, the damage by the high water last December was only some tens of thousands of dollars, but it is an indication of what may occur in the future, and still the Chagres deflections are hardly begun. On the Panama side of the divide, where dredged work has nothing to fear from wash-down, and where the opened canal would be most useful for removing spoils, no dredging has been done.

The lack of power drills, the seemingly too extensive use of small material, the want of good switching and double lines for spoils trains, and the ineffective excavators have all been mentioned in this report; all of which would seem to indicate that the work is being done in a slower and more expensive way than is necessary. The only explanation I have heard is that, for financial reasons, it was considered best to show as soon as possible a good cubic extract from the basin of the canal, and that consequently the work was pushed with such material as could be easily secured, much of it small, and some of it, especially excavators, of a kind designed for Suez but not at all suitable for Panama.

I was much surprised that there is no intention of using hydraulic practiced in the United States, especially as it could be so cheap... At Culebra, for example, a small dam on the Rio Grande Superieur w... sufficient water for a 2-inch pipe for four or five months in the year. ... would be between 30 and 40 metres, and the fluming required to ... water to the working site not more than 600 or 800 m. long; the ... washing down to the Paraiso plain is 1.5 to 1, certainly enough to ... spoils. Considering the work that could be done by that size of head of water together applied by a choke-bored monitor, it w... seem as if the mass at Culebra could be easily taken down to the ... and then dredged and dumped much more cheaply than it can be ... the present method of small excavators and small spoils trains. I... informed that an offer had been made to wash Culebra down to ... on the Panama side of the divide for 30 cents per mc.; and t... been made to wash down the whole section, where washable, ... the rock, disposing of the wash spoils by mud-pumping it over ... the rock by dumping it well clear of the banks; to furnish all ... plant, and to finish the work in two years at $2 per mc. fo... $300,000 bonds to insure performance. The reason given me b... for the declination of the proposal was that no American ... wanted, and besides that hydraulics were not approved by the ... sees. To me it is patent that the Company had a better reason ... It may have suffered at the hands of American contracto... but ... imagine that it would not use the methods that would be to it... or that the high talent of the Ponts et Chaussées would not g... of hydraulics. Still the fact remains that there is no prepar... them, which is all the more curious when one remembers ... barrage would give power for work all along the line with v... compared with the amount used in the United States for ... operations. One hears on the Isthmus a considerable am... regard to national jealousy; that neither American ... machines, American methods, nor American workmen are wanted; ... mechanics accuse American ones of trying to break down the ... order to stop the work, so that the Americans can get control ... and much other such wild statement, which would appear to be ... in words of the discomfort arising from mental depression due t... malaria.

### THE CHAGRES PROBLEM.

The plan for the barrage already given seems to me quite s... do not understand the necessity for excavating for a f...

not conceive that the river could greatly displace a mass of rock dumped on the soil and in the bed. The slope at Gamboa is not sufficient to greatly aid the sliding of the rock, if it were dumped and the current allowed to cut the soil from underneath it, and consequently the rock would only sink until it found a solid foundation. Even if in building the rock were somewhat displaced, it would be only a question of dumping more. When built, no pressure of the water could push *down* a mass ten times as wide as it was high, nor can I conceive of its pushing such a mass *along*. Mr. Menocal, in his report, speaks of the grave engineering difficulties in building this barrage, but I understand that he was then speaking of the first project for a masonry dam. The enormous amount of work necessary for the construction of a barrage at least 40 m. high, 400 m. wide, and more than a mile long, is apparent, but the engineering difficulties are to me not at all patent. That the basin will be ample for holding the floods till the water can be drawn off through the tunnel, there seems to be no doubt. In fact, as regards the barrage and basin, the margins of safety are fully large enough, from my point of view. It should be borne in mind, in this connection, that the great rises in the Chagres do not mean an immense discharge. The floods at Matachin are of short duration, showing that they result from large local rainfall, but not from extensive water-shed. The accompanying tracing of the section of the river at Matachin at the time of the great flood, on the 25th November last, illustrates the rapidity of rise and fall—of the comparatively small amount of discharge there would be in ten days, although very great for one or two. The rise and fall of the river at Gamboa depends very little upon the rainfall there, not even when the fall for a month is considered; for example, last year the greatest monthly rainfall was in September, and was in the 19 rainy days of the month 408.9 mm., the average height of the river being 16.28 m., and the highest water 18.33 m. In the 19 rainy days in November the fall was only 336.30 mm., and the lowest water was 15.70 m., while the highest was 23.72 m. The rise was very rapid at the time of the flood.

At 7 A. M., 25th November, the river stood at 15.7 m.
At 7 P. M., 25th November, the river stood at 19.73 m.
At 7 A. M., 26th November, the river stood at 21.14 m.
At 7 P. M., 26th November, the river stood at 23.72 m.
The next day it was down to about the average level of the month.

Dead low water at Gatun in the dry season is 14.85 m. I have been particular in speaking of the flood because it is the highest there has been for seven years, and, therefore, a good example of what may be expected and of what the basin may have to hold. It is evident that the basin would easily have controlled the water coming down in that flood. With the barrage built, the deflections cut, and the embankments in place, the Chagres problem can, I think, be solved. Winslow speaks of the necessity of solid embankments at points where the canal crosses the Chagres at San Pablo, because at times the river rises 30 feet at Barbacoas. It is true that the river does so rise, but if the basin at Gamboa holds the surplus water and sends down only 400 m. c. s. through the deflections, the duty of the embankments will be to resist, not the torrent rising 30 feet in a night, but the stream corresponding to not more than 400 m. c. s., no matter what may be the conditions of floods above the dam. The embankments must be solid enough to resist the tunnel outflow, but they need be only high enough to bring the wide bed cut off to the section of the deflection. On the whole it seems to me that the Company has found the solution of the Chagres problem in theory, but the work necessary to put it in practice should have been some of the very first undertaken, when, as a matter of fact, it is hardly begun. Nearly all of the deflections are to be cut, and all of the embankments and barrage built.

No conclusions as regards time can be arrived at by manipulating the figures of extracted and remaining cubes. The Company has doubtless made some grave mistakes, but I am confident it has at its disposition all the necessary

brains and energy. As for human life, that is always cheap. The question of finishing the canal is then almost entirely one of finance.

From all the preceding it will appear that I have arrived at no conclusion as to whether or not the present company will finish the canal or when it will be finished, if at all; but from inspection, investigation, and observation I have become strongly impressed with the idea that if M. de Lesseps succeeds in placing the new lottery loan of 600,000,000 francs, if the money so obtained is expended with the economy that has lately shown itself in the Company's affairs, and if the work is energetically pushed by the best methods, the canal will be so far advanced by the time the money of the new loan is expended that the necessity for finishing it will be apparent." W. F. W.

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## BOAT-DETACHING DEVICE.

Invented by L. J. M. Boyd, Annapolis, Md.

The object of the device is to make it possible to detach a boat with promptness and certainty in any condition of weather. A hook is provided in each end of the boat, and is so swung that it will detach itself from the ring in the lower block of the boat-fall whenever it is set free by the movement of a detent. The detents (G) are operated by a single lever (H) through rods. After the lever is moved the falls cannot be hooked on until the lever is restored to its original position. The hooks are allowed to swing so far that they will detach, no matter at what angle the falls may lead away from them. The weight of the hook causes it, when set free, always to return to the position for hooking on, but to make this more certain a strong spring is also provided. In case it should be desired to overhaul the apparatus while the boat is at the davits, a pin is fitted to lock the hook and allow all other parts to be removed at leisure. The hole through the hook for the pin is enlarged so that there is no strain on the pin (I), when the detaching lever is in place. The length of the rods attached to the lever can be adjusted to allow either end of the boat to be detached a little sooner than the other. By putting in one of the locking pins, either end of the boat can be detached and leave the other hooked on securely. The rods are covered in the bottom of the boat, and the lever placed forward of and a little below the level of one of the thwarts, to be accessible and not in the way. For a four thousand pound boat a pull of only eighteen pounds on the lever is required to detach it. All parts of the device except the rods are cast, and are so made as to require very little finishing by hand or machine after leaving the foundry. They are made of malleable iron, phosphor or manganese bronze. The following is the report made by the Board appointed to test the device:

[Copy.]

U. S. Naval Academy,
Annapolis, Md., *October* 19, 1[illegible].

Commander W. T. Sampson, U. S. Navy, *Superintendent.*

*Sir:*—In obedience to your order of October 19th, we have examined boat-detaching apparatus proposed by Mr. L. J. M. Boyd, as fully as p[illegible] in smooth water.

The apparatus was fitted to one of the cutters of the U. S. [illegible] now alongside of the wharf. The boat was placed in as many cond[illegible]tions as possible and then detached. The apparatus worked [illegible] and we can say that, as far as we can judge from the above trials, [illegible] apparatus we have seen.

We enclose drawings of the apparatus. The cost to put it on a b[illegible] be about $20.* The ring necessary for the lower block can be ho[illegible]

[illegible]unt does not include the cost of the labor necessary for attaching it to

The apparatus is simple and takes but little room. The following are some of its principal advantages: The boat is easily hooked on at any time and the falls cannot unhook again. There is very little weight on the detaching lever, and therefore no liability to jam. The one lever detaches both ends of the boat. The connection between this lever and the apparatus in the ends of the boat is made of rods, so that there is no liability of fouling. The falls cannot unhook themselves in case any part of the boat becomes water borne. Should the boat be in the water before the lever is thrown back, the slightest strain on the falls will unhook them when it is thrown back. Safety pins are also provided with which to secure the hooks if it is thought desirable. They are arranged so that there is no strain on them as long as the lever is secured, they can therefore be pulled out easily. By leaving either of the pins in, the other end of the boat alone can be detached.

We would recommend the apparatus to be tried in some sea-going vessel, in competition with the best apparatus used in the service.

Very respectfully,

(Signed) C. T. HUTCHINS, Lieut.-Commander, U. S. N.
E. H. C. LEUTZE, Lieutenant, U. S. N.
C. E. COLAHAN, Lieutenant, U. S. N.

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## REPORT OF THE HOISTING OF THE ONE HUNDRED-TON DERRICK, MARE ISLAND NAVY YARD, CAL.

By Civil Engineer C. C. WOLCOTT, U. S. N.

NOTE.—The construction of a derrick or shears with capacity for lifting one hundred tons was authorized by Congress, March 3, 1885, the sum of $40,000 being appropriated for that purpose, and the 4th of August, 1886, an additional sum of $22,000 was appropriated.

On account of the excessive amount of the bids offered in answer to the advertisements for proposals, the plans were changed from the form of a crane to that of shears, and the work was authorized to be performed by the Steam Engineering Department of the Mare Island Navy Yard, under the direction of Chief Engineer George F. Kutz, U. S. N., in accordance with estimates submitted by him. The shears was successfully constructed by Chief Engineer Kutz at a cost of $37,152.07. The foundation and the erection, which is described in the following report, under the superintendence of Civil Engineer Wolcott, U. S. N., cost $7,223.18; making the entire cost of the shears in place, and including all labor and material, $44,375.25.

It is gratifying to note the success with which the navy yard force has completed this undertaking at a less expenditure than it would be possible to have the work done by private parties. It is one of several instances that has occurred at the same navy yard, wherein the navy yard workshops, notwithstanding the eight hours' system, has successfully competed with private establishments, both in regard to workmanship and cost. It is an evidence of what can be done at navy yards if the establishments are properly managed.

The Bureau of Yards and Docks took pleasure in acknowledging the success and ability of the officials concerned in this work, and the chief of the bureau in a formal manner tendered his thanks to them for the efficient manner in which the work was performed. C. H. S.

DEPARTMENT OF YARDS AND DOCKS,
CIVIL ENGINEER'S OFFICE, U. S. NAVY YARD,
MARE ISLAND, CAL., *June* 20, 1887.

*Sir*:—I have the honor to submit the following report of the operations attending the hoisting of the 100-ton derrick, and the subsequent trial when completed, ready for use.

... were completed in June, 1886, ... the annual report of that year; but for ... of the whole structure, it is

... was commenced on June 3d. ... hard pan and sand rock at a ... and from ... at the positions ... the low tide mark, it was ... sawn off at extreme low tide. ... An area 12 × 12 feet was ... and driven to ultimate resist- ... bolted to the piles; across ... same sized timber, also bolted firmly to ... and the piles together. On this ... with great vigor, was built up with battering ... the cast-iron shoes of these legs. The ... on these piers.

... to a change to one of small compression ... did not require such heavy piling; the ... in a longitudinal direction, and 5 feet in a ... the hard pan. The excavation for this ... was carried down to a line of low tide, at which point the piles were ... the shorter axis with 12 × 12 timber drift bolted to ... was laid other timber of the same size, laid in ... At the outer end, where the maximum load in tension ... straps made of 2-inch iron forming a hook in ... a flat lower one, were bolted to the timber below the ... bolted to the rows of piles; all these ... The hooks in the upper ends extend through the ... through these hooks railroad iron was run.

... the track along which the crosshead of the back ... iron, with an eye turned in the lower end and a ... These bolts were 11 feet long, and ... to the railroad bars, which in turn were placed under ... described. These long bolts were spaced along the ... to the load to be borne, and varied from 7½ inches ... at the rear end.

... were placed over these bolts to hold them upright, and after a ... the concrete base was laid on the floor ... and around these long bolts; thus all was built ...

... are all in the same vertical plane and extend through the con- ... would tend to split the concrete.

... together, transverse bolts with 12-inch square ... at various distances in both a vertical and horizontal ... This made a mass 56 feet long and ... together in a most thorough manner.

... below the permanent water and will never decay. The ... and will not rust.

... about these foundations was thoroughly puddled and ... the foot plates and trunnions for the front ... for the back leg had been completed, they ... position on these foundations.

... the various parts was completed, the legs ... the steam engineering shops to the site and ... The lower ends of the two front legs were placed ... the foot plates, and the pin about which they are to ... the upper ends in proper position, and the back

leg was laid out in prolongation of the other two, and with its head between the others it was pinned there; the heads of the three were then raised by hydraulic jacks to allow the upper blocks to be hung. The derrick was thus spread out, and the distance from the lower pin hole in the front legs to that in the back leg was 246 feet.

The weight to be raised in the first moments of the lift was 54 tons, and the lower end of the back leg had to move 163 feet before it could be secured to the crosshead.

To raise these legs it was necessary to raise temporary shears, and which must be so placed that the legs would pass over them and yet not be in the way of the back leg when it came in position. The three longest and largest spars were borrowed from the Department of Construction and Repair; they were 81 feet long and 40 inches in diameter at the butt. In order that no delay should occur when once the operation of raising commenced, to change the purchase or remove other shears, only one set of shears was used, and these three spars were raised and lashed together with the feet of two of them inside of the main legs and 24 feet distant from the pins in the lower ends. This was as near as they could be placed to the head of the derrick, on account of the small distance they could spread. A large three-sheave block was secured as high on these shears as possible, and was 72 feet from the ground.

A toggle of large beams was made fast to the lower legs, 11 feet from the upper end, and to this were lashed the other blocks; the drift between the blocks was 100 feet. This position of the blocks, which was the best under the conditions, gave with the weight to be raised a strain of 54 tons at the first lift, and when the two blocks came opposite each other the head of the derrick would be only 72 feet above the ground, and from this point it would be forced into place by hauling on the foot of the back leg.

The U. S. S. Hartford was made fast to the sea wall to serve as a holdfast for the guys for the temporary shears, and to allow of the use of her steam capstan for the hauling power on the main purchase. Six guys were led aboard and made fast to toggles laid across the beams of the berth deck, and a leading block laid in the gangway made a fair lead to the capstan.

As the back leg had to move forward as the head was raised, a boat of heavy timber was placed under the heel and resting on a bar, which in turn was secured to the leg so that it might turn as the head was raised. This boat rested on box rollers laid on a track of beams, which extended to the point where the crosshead was to be met, and which was run back on the turning screw to its furthest limit.

On either side of the back leg near this boat, heavy tackle was made fast, the other being secured to chain cables passed around the foot plates of the front legs; the hauling part of the side tackle was brought to a windlass on either side; these were worked by horse power.

The resultant of the weight of the front legs and the reaction of the power necessary to raise this passed outside the centre base of the front legs, and there was danger of overturning these pair as well as the sea wall. To prevent this, large anchor chains were placed around these foot plates and the rear end of the track of the back leg.

Commencing at 7.20 A. M. the derrick was raised to the highest point possible by the main purchase, and then the side tackles were brought into operation and the back leg run into place and secured to the crosshead. There was no accident or hitch of any kind, and all worked very smoothly.

Great credit is due to the men engaged in this, and especially in the service and skill of Bart Willman, a first class rigger, worthy of commendation, for he was entrusted with the placing of the rigging, and that no accident occurred in its progress is largely due to his attention.

The next day the wooden shears were lowered by means of the new derrick. After their removal, the hoisting engine, drums, and boiler were put in place on foundations already prepared for them, steam was gotten up, and the various parts tried, though no weight was used.

Everything worked in a perfect manner. The hoisting gearing is easy to control, and the traversing of the back leg is smooth and uniform in its movements.

The derrick can now be regarded as complete and ready for service, and will fully meet all the requirements. The limit of the load to be placed on this machine can with safety largely exceed 100 tons.

The workmanship on the metal part of the derrick is of the highest order.

*The Foundation.*

| | |
|---|---|
| Cost complete, . . . . . . . . . . . . . . . . . . . . . | $4,976 17 |

*Erection.*

| | |
|---|---|
| Cost complete, . . . . . . . . . . . . . . . . . . . . . | 1,493 13 |
| Filling in around foundation, restoring roadway, hauling, plans, &c. | 758 88 |
| Total, . . . . . . . . . . . . . . . . . . . . . | $7,228 18 |

Appended is a tracing of the foundations as they exist.

Very respectfully,

C. C. WOLCOTT, *Civil Engineer, U. S. N.*

Captain BYRON WILSON,
*In charge of Department of Yards and Docks,*
*Navy Yard, Mare Island, Cal.*

Respectfully forwarded, BYRON WILSON, *Captain, U. S. N.*

COMMANDANT'S OFFICE,
NAVY YARD, MARE ISLAND, CAL., *June* 21, 1887.

Forwarded for the information of the Bureau.

GEORGE E. BELKNAP, *Commandant.*

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## THE NAVAL COMBATS IN THE WAR OF THE PACIFIC, 1879–1881.

By LUIS URIBE Y ORREGO, Captain, Chilian Navy.

(An Abridged Translation by Prof. JULES LEROUX.)

In this volume, the naval engagements in the Pacific between Chili and Peru are for the first time considered under their technical aspects, in a full and interesting analysis, the object of which is to set forth the instructive lessons taught by each of them. Leaving aside the causes of the war, the author lays great stress on the facts, until lately disputed, but now generally admitted, that Chili was totally unprepared for the contest, and that the situation of her Navy in particular was critical, but still, on the whole, that the forces that were about to dispute the supremacy of the sea were not far from equal.

On the 12th of April, 1879, Captain Latorre, of the Chilian lánes, on a mission north, sighted to the northeast, and bear him, the Peruvian corvettes Union and Pilcomayo, and th have avoided an encounter, he determined to fight his way running fight the Union suddenly bore up and gave up the chase on the part of the Peruvian corvette has been variously c According to Commander Latorre, the Union was forced to a owing to serious damages to her machinery from the effects of two 11 shots from the Magallánes. The escape of a great quantity of funnel of the corvette coinciding with these shots gives at l

blance of probability to his statement. On the other hand, it is denied by some that the Union was at all injured by the firing from the gunboat, and they explain the unusual movement of the corvette by the bursting of her boiler tubes, owing to a too heavy pressure of steam, in her efforts to come up with the Chilian vessel. It must be remembered, however, that the Union possessed superior speed, and was at least a half knot faster than the Magallánes, from which she stood only at 2300 metres, that is, within fighting distance. It is also singular that the commander of the Union makes no mention whatever of this accident to the boilers of his vessel, in his official report.

Though lacking in interest as a subject for study, this action nevertheless points out the necessity that vessels which, owing to their relative inferiority, may be forced to refuse the combat, shall so arrange their guns that the heaviest piece may be trained to fire astern. If the Magallánes had been able to point her 115-pounder pivot gun right aft, it is doubtful whether the Union would have followed in her wake; and, *vice versâ*, if on this occasion the corvette had been armed with efficient bow chasers, it would not have taken her long to put her antagonist *hors de combat*. In support of this it is only necessary to cite the deadly fire that the Cochrane maintained on the Huascar in the engagement off Punta Angámos, when the latter vessel made the fatal mistake of turning and running before the Chilian ironclad within gunshot. Nobody ignores the importance of parallel firing, especially since the introduction of armor and the ram in naval warfare.

The general use on board of men-of-war of the automobile Whitehead torpedo, with its perfected method of handling, is another factor in attack and defense which will render hazardous hereafter the pursuit of vessels provided with this class of weapons. The hesitation of Captain Grau of the Huascar in attacking the Esmeralda at close quarters, during the engagement at Iquique, while he was in doubt as to the presence of torpedoes on board the Chilian, lends support to this idea, and its truth is further demonstrated by the ludicrous incident that took place later on, between the same Huascar and the Matias Cousiño. The Matias Cousiño was a Chilian transport loaded with coal intended to be transhipped at sea to the other vessels of the squadron during the expedition against Callao. The transhipment was to be made by means of two barges hung on each side of the transport. Somehow the Matias Cousiño got separated from the rest of the squadron the first night out, and she remained cruising off the coast for nearly two weeks. One evening her captain sighted a steamer to the southward. Not doubting for one moment that it was one of the vessels of the squadron in search of him, he steered straight towards it. But, to his astonishment, the stranger bore away and headed west. Still unsuspicious, he followed the fugitive. Just as the sun went down, the fog, which had been very thick, cleared a little, and to his horror, the captain of the Matias found himself close in the wake of the dreaded Huascar. Captain Grau had also recognized the adversary before whom he was fleeing, and the face of affairs suddenly changed. Terror lent wings to the transport, she turned and fled, with the monitor in hot pursuit. In order to lighten his vessel, and also to oblige his pursuer to alter his course, Captain Castleton cut loose his two barges one after the other. This stratagem had an unhoped-for result. Captain Grau, who had already been deceived by these barges, whose position on board the Matias gave the latter the appearance of an ironclad with its citadels, which explains his previous flight, seeing them coming towards his vessel, in the dark mistook them for torpedoes, and night fall adding to the probability of meeting the Chilian ironclads off Iquique, he gave up the chase and headed north. We have related the above incident somewhat at length in order to show to what use a vessel closely pursued or threatened with ramming could put her torpedoes.

When, on the 17th of May, 1879, the main portion of the Chilian squadron sailed north on their expedition against Callao, two small wooden vessels, the corvette Esmeralda and gunboat Covadonga, were left in charge

of the blockade of Iquique. This was a good opportunity for the Peruvian ironclads Huascar and Independencia, which had obtained knowledge of the movements of the enemy's squadron. On the 21st they suddenly appeared off Iquique, and at once began the attack; the Huascar choosing the corvette, and the Independencia, the gunboat. The Huascar was the first to open fire on her antagonist, and for two hours a lively cannonading was kept up on both sides; yet, so great was the want of training among the Peruvian crew, that during all this time they succeeded in planting only one 300-pound shot in the sides of the corvette, whose feeble artillery failed in turn to make the least impression on the armor of the monitor. Captain Grau then determined to try his ram in order to bring matters to a conclusion. Twice he struck the corvette; the first time with no apparent result, but the second, with palpable effect. The boilers of the Esmeralda were in the worst possible condition, and with her reduced speed she was unable to avoid the full force of the shock of the ram. The monitor struck her on the port bow at an angle of 45°, leaving a gaping aperture through which the water rushed into the engine room, extinguishing the fires and flooding the powder magazine. The corvette was now perfectly helpless—she lay motionless on the water; but, as she would not surrender, Grau had no alternative but to ram a third time, striking her full on the starboard side. The corvette went down almost immediately, with her colors flying at the peak.

Meanwhile the Covadonga, exposed to the furious attacks of the Independencia, made all efforts to escape. Hugging the rocky coast as close as the shallow water would permit, she lured her adversary after her over the shoals of Punta Gruesa. The inexperience of the gunners of the Independencia was here made as manifest as that of the Huascar's, and, in spite of his overwhelming superiority, Captain Moore despaired of putting an end to this protracted combat. He, too, decided to resort to his ram. After one or two futile attempts he finally saw his opportunity. Unluckily, at the most critical moment the men at the wheel were shot down, and the vessel falling off, was fast aground in an instant. The Covadonga stopped one moment to take the offensive, but the appearance of the Huascar on the scene obliged her to resume her flight south, and though leaking badly, and carrying only five pounds of steam, she escaped, no doubt owing her safety to the time lost by the monitor in communicating with the Independencia when she hove to abreast of her wrecked consort. Grau in his official report makes no mention of his stopping, but on the contrary leaves it plainly to be understood that he pursued the Covadonga for three consecutive hours. It is hard to reconcile the two versions. Indeed, the fact that Punta Gruesa is situated 11 miles south of Iquique, and that at this date the Huascar's speed was 10½ knots an hour, whilst that of the Covadonga did not exceed five, makes it evident, admitting the correctness of Grau's statement, that at the end of a 3 hours' chase the monitor would have stood 19 miles south of Punta Gruesa, i. e. 3 miles further south than the gunboat, which could not have covered more than 15 miles in the same interval.

In corroboration of the above we will relate the following: The officers of the Esmeralda, who had been placed under guard in the … of the Huascar, remembered distinctly that the monitor, which … running at full speed, stopped suddenly and lowered one or more … they could tell by the peculiar grating and creaking of tackles … operation), and started again immediately afterwards. Later … Peruvian officers came down in the room, and entering into con… the first prisoner he met, inquired casually about the speed of … His interlocutor chanced to be the assistant surgeon of the Es… had only a month before set his foot on board a man-of-war for the … The young doctor, little versed in such matters, answered … … Covadonga was 10 miles an hour. The Peruvian … …ied up on deck, and shortly after a peculiar

announced to us that she had altered her course and probably headed north. Evidently her commander, misled by the intelligence just received, had given up all hope of catching the gunboat and abandoned the chase.

The above little incident shows also the advisability of keeping at all times, but especially in times of war, the general public in ignorance of the speed of the vessels of a squadron. Had Grau remained even the least doubtful about the rate of the Covadonga, it is not likely that he would have so easily relinquished the pursuit of the latter.

Speaking of the rate of a ship, we are put in mind of that frequent and always perplexing question, "How fast is your vessel?" In order that a steamer may develop at all times its maximum speed, a combination of various elements is requisite, such as a well trained and sufficiently numerous *personnel* in the engine room, coal of good quality, and a clean bottom. The war of the Pacific furnishes many examples showing that the quality of coal is of as vital importance as any other fighting element of a ship; and one would not be far wrong in venturing the opinion that the capture of the Huascar by the Chilian ironclads was in a great measure due to the inferior quality of her coal as well as to her foul bottom.

The action of Iquique does not present sufficient data from which to determine conclusively the value of attacks with the ram; the contestants were too unequal in size, build, and armament. It must be remembered, too, that the Esmeralda, owing to the bad condition of her boilers, was almost motionless. Yet, in spite of that, she only succumbed to a third attack of the ram of the Huascar. If we compare these attacks with the fruitless efforts of the same Huascar in assailing the Magallanes, a few weeks later, in the same waters and under almost identical circumstances, when the monitor did not even succeed in scratching the paint on the sides of the corvette, we may be excused for feeling less sanguine as to the efficiency of that weapon, than those who are of opinion that the ram is destined to play a most important and decisive part in modern naval warfare. After all, what has been said and written on the subject up to this day are isolated opinions and mere conjectures based mostly on theoretical calculations, which, on being put to the proof and transferred to the field of action, which is the sea, either fail entirely or fall short of the expected results. And it cannot be otherwise; the same thing happens with experiments in the perforation of armor plates. It is not a rare thing to hear, or even read in scientific reviews and periodicals, that since guns can be made to pierce the heaviest armor that can float, there is no excuse for the existence of armor-clad ships. Those who reason thus do not seem to take into account that the *penetration tables* are based upon experiments made on land under circumstances most favorable to the gun and most unfavorable to the plates.

The loss of the Independencia was a terrible blow to the power of Peru; yet, while the Huascar was free to commit hostilities along the Chilian coast and baffled all efforts to capture her, Chili could not undertake any serious land operations. Orders were therefore given by the Government to capture or destroy the Peruvian monitor at all hazards. Without loss of time, the commanders of the squadron determined upon the following plan of operation. Having noticed that the Huascar whenever she was pursued always changed her course to westward and then headed northward, it was agreed that the slowest vessels of the squadron, the Blanco Encalada and Covadonga, should sail south along the coast at a distance of from five to six miles, whilst the Cochrane, O'Higgins, and the Loa should cruise at sea, keeping well off the land, say about 20 miles from the nearest cape.

Early one morning, the 8th of October, 1879, the Blanco Encalada sighted two steamers coming from the direction of the land and apparently bent on reconnoitering. The division at once bore down upon them, when they altered their course and sailed in an opposite direction. This circumstance looked suspicious, and the thought of the Huascar flitted through the mind of the Chilian commander. He was right. Daylight revealed the Peruvian monitor

and her consort, the Union, fleeing at full speed before him. He then signalled the vessels of his division to slow up, so as not to force those of the enemy too far west. These, feeling safe from pursuit, altered their course as had been anticipated, and headed north under easy steam. One hour thus passed in chase, the Blanco Encalada meanwhile forcing her fires as much as the bad condition of her boilers would permit, and anxiously scanning the horizon for the division that was to intercept the fugitives. Finally, the lookouts at the masthead descried columns of smoke in the northwest, and shortly after it became evident that the other division was manœuvring to head off the Peruvian ships. Grau, seeing himself caught in the trap so skillfully laid for him, and the impossibility of avoiding an engagement, signalled his consort to part company and make all efforts to escape north. This the Union found no difficulty in doing, thanks to her well known speed.

The combat of Punta Angamos, thus named from the headland off which it took place, has been described and commented upon with more or less accuracy by the El Mercurio, which had a correspondent at the seat of war, and by foreign naval officers, among them Lieutenant Mason, U. S. N., and also by Mr. Clements R. Markham, in his work entitled "War between Peru and Chili"; it is therefore useless to describe it here. We cannot help remarking, however, that the comments of some of the writers and the conclusions reached in regard to the movements and manœuvring of the Huascar in that engagement are erroneous.

Let us first consider the chances of escape of the Peruvian monitor, or if that was impossible, then the means for the offensive she had at her disposal. In our opinion, at the moment she sighted the Cochrane, several courses lay open before her:

1. She could put about and fight her way south against the Blanco if she found it impossible to avoid an encounter.

2. She might try to escape to the northeast between the Cochrane and the land, trusting to her heels as she had so often done before successfully.

3. She could steer southwest without fear of being molested by the Blanco, drawing after her the Cochrane, whose speed did not exceed hers by more than half a knot, and over which she had a lead of at least 12 miles.

As is known, Grau chose the second course. Had he chosen the first instead, i.e., had he veered around and attempted to escape south, he would not perhaps have found it very hard to avoid the Blanco, whose speed did not exceed [illegible] knots; but if he steered in that direction, then the southwest lay open before him. Finally, having adopted neither of the last two plans, and finding an encounter with the Cochrane inevitable, his best chances were to bear straight down upon the latter and attack her resolutely, thus equalizing the offensive powers of the two vessels. But the Peruvian admiral allowed the Cochrane to take up her position on his stern, and thus resigned himself without a protest, so to speak, to his fate. Some will claim, perhaps, and, among others, Lieutenant Mason in his pamphlet, "The War on the Pacific," that the Huascar made attempts at ramming the Cochrane. Let us examine the facts. Before Grau was killed, that is, during the first half hour of the engagement, it is well known that all the energy of the Huascar was concentrated in her efforts to escape to the northeast, and if, while heading in that direction, she once sheered a little to port, she did it in order to bring the guns in her turret to bear, and not, as is asserted by some, in order to ram the Cochrane. After the death of Admiral Grau and the disabling of her steering apparatus and speaking tubes, the Huascar was completely unmanageable, that is, as far as precision of [illegible] attacks with the ram were concerned. Finally, some at least of the supposed [illegible] attacks, admitting there were any, were not such in reality. [illegible] the bad steering of the monitor, which, on [illegible] repeatedly, owing to a deflection of her [illegible] towards the Cochrane, then to the Blanco, and the Matias Cousiño; a fact which explains partially the statement of

Captain García y García, of the Union, who represents his unfortunate consort as fighting right and left against the whole Chilian squadron. Experience has shown that it was impossible for the Huascar to maintain her course at full speed with her temporary steering gear. It then remains demonstrated: 1. That while it was in the power of the Huascar to use her ram with more or less success, *i. e.* during the first half hour of the engagement, she did not do so. 2. That later on the only time she attempted to use it, she was prevented from carrying out her intention by her bad steering.

One of the many lessons taught by the action of Angámos is the advisability of providing for the ship's commander one or two secondary protected stations supplied with speaking tubes connecting with the engine room, the wheel house, and the battery respectively.

When we consider that it is from the captain's station that proceed all the orders which give life and motion to that costly and complicated engine of war called a modern ironclad, and further that upon the physical and moral ability of the occupant of the turret will depend, in the majority of cases, victory or the most terrible disaster, we cannot surround him with too much protection. As will be remembered, the pilot house of the Huascar was destroyed almost at the beginning of the action, and with it the speaking tubes, rendering communication with the engine room and the wheel very difficult.

Some of the remarkable features of this memorable fight, aside from the foregoing considerations, is the frequency with which the Huascar was hit, nearly one-third of the shots telling, and the repeated disabling of her steering gear; the first being due, no doubt, to the strategical position of the Cochrane on her quarter, and the second, to the exposure of her steering apparatus above the water line.

One word in regard to the demoralization and confusion created among the crew by the terrible effects of the bursting of the Palliser shells in the interior of the monitor, which were the immediate cause of her surrender, since it may be said that her vital parts were intact. It has often been said by the friends of unarmored vessels that it matters little for the final result whether the portion of the hull above the water line were honeycombed (such is their expression) with shot, as long as the vital parts and the engine remained intact. It is evident that those who reason thus have not taken into account the demoralizing effect produced among the crew of a vessel by the bursting of the shells in its interior, especially when engaged against an adversary whose guns are protected by armor.

The last act of the drama was played. The capture of the gunboat Pilcomayo, November 18, 1879, and the engagement of the Chilian fleet against the forts of Arica, present no features of salient interest.

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## FRENCH PROTECTED CRUISERS.

(From *Le Yacht*, September 24, 1887.)

The Minister of Marine has advertised for plans for barbette cruisers of the first and second class. For the cruisers of the first class, the hulls are to be entirely of steel, and are to be protected at the water line by a belt of armor 10 cm. in thickness. The conning position and guns are to be protected by shields of the same thickness. A steel deck is to extend fore and aft and a coffer-dam around the ship. The division of the ship into water tight compartments is to be as complete as possible. They are to have two military masts and are to carry two 47-mm. guns on each top. Each is to have four torpedo tubes. The armament is to be: two 10 cm. and six 16 cm. guns, on hydraulic carriages, distributed in such a way that five pieces can fire at the same time either ahead, astern, or abeam. In addition, they are to have two

65-mm. and four 47-mm. rapid-fire guns; eight 37-mm. revolving cannon. The speed is to be, with forced draft 20 knots, with ordinary draft 17.5 knots. They must be able to run four thousand miles at 12.5 knots. The crews are to consist of four hundred men. Each cruiser is to be lighted with electricity throughout.

The cruisers of the second class are to have the same general arrangements. The armor is to be 8 cm. instead of 10 cm. The armament is to be: two 16-cm. and six 14-cm. guns; two 65-mm. and four 47-mm. rapid-fire guns, and eight revolving cannon. They are to have three armed tops, the fore carrying two 47-mm. guns, the others one each of 37-mm. Each is to have four torpedo tubes. This class are to have four steel masts, rigged square on the fore and fore and aft on the others. The speed is to be the same as those of first class. The crews are to consist of 300 men. Each is to be lighted by electricity.

D. H. M.

# BOOK NOTICES.

THE HOTCHKISS SYSTEM OF RAPID-FIRING GUNS. Printed for private circulation. London and Paris, 1887.

Containing descriptions and illustrations of the 37, 47 (light and heavy), 57, and 65-mm. guns, and 10-cm. gun, with their ammunition, mounts and carriages for the naval and military services, together with firing tables and penetration diagrams, as determined by official tests on the firing grounds of Europe and the United States.

This book is written in a clear style and much detail is observed. It shows a decided advance of the rapid-firing system by its application to larger guns. Some space is devoted to the quality of the steel employed in the manufacture of Hotchkiss guns, and also to the strength of the guns. A chapter is devoted to the efficiency of the rapid-firing gun in defense from torpedo-boat assaults. In this the author advocates with reason the use of the tangent bar-sight in preference to the ladder sight, and from a consideration of the trajectory, ranges at which the gun will be used, and the chances of hitting, arrives at the conclusion that the best range at which to set the sight bar permanently, it being impracticable to change it during a torpedo-boat attack, is 800 yards for an arc covered by only one gun. Where two guns cover the same arc, one should be set permanently at 750 yards and the other at 900 yards, to ensure the greatest number of hits. The author names 600 yards as the range for which the sliding leaf should be compensated to allow for wind and speed, and lays great stress upon firing only with a direct aim at the object.

In addition to what is contained in previous issues on the same subject are descriptions of shrapnel for the rapid-fire guns with the Elswick combination time and percussion fuze, together with the Hotchkiss and Desmarest pose fuzes for shell.

A drill cartridge is devised in which service rifle ammunition may be used. This cartridge admits of reloading, and only necessitates marking the rear sight for this ammunition. The larger calibres 65 mm and 10 cm. are also new. A general description of the rapid firing gun applicable to all calibres is given, but no detailed description of individual guns or nomenclature of parts, as in previous issues. The gun drill is also omitted. In addition to the military mounts are described the non recoil or crinoline mount, the Elswick and Hotchkiss recoil mounts, and a pivot carriage for the heavier guns. The directions for mounting and dismounting are very clear and complete. The illustrations are in thirty-four plates from photographs.

The book as a whole is very interesting and instructive, and is obviously well worth perusal by naval and military officers. J. H. G.

FROM Carl Gerold's Son in Vienna we have received Pola, Its Past, Present and Future. This brochure contains a very readable history of the city from its foundation by the Romans in 178 B. C. to the present time. The whole is accompanied by cuts and maps. The book is of interest from the fact that Pola is now the seat of the principal dockyard and naval arsenal of Austria.

J. F. S.

## CONTRIBUTIONS TO THE LIBRARY.

We wish to acknowledge the receipt of the following books for the Library of the Institute :

LOS COMBATES NAVALES EN LA GUERRA DEL PACIFICO, 1879–1881. Por Luis Uribe y Orrego, Capitan de Navio de la Armada de Chile. Presented by the Author.

WAR OF THE REBELLION. OFFICIAL RECORD OF THE UNION AND CONFEDERATE ARMIES. Vols. VI–XIX. Presented by Prof. M. Oliver, U. S. N.

SURVEY OF THE NORTHERN BOUNDARY OF THE UNITED STATES FROM THE LAKE OF THE WOODS TO THE SUMMIT OF THE ROCKY MOUNTAINS, with Atlas. Presented by Prof. M. Oliver, U. S. N.

A TREATISE ON ARTILLERY. By H. Lallemand, General of the Artillery of the late Imperial Guard of France. 1820. Vols. I. and II. Presented by Prof. M. Oliver, U. S. N.

THE PRACTISE OF ARTILLERIE. By Robert Norton, One of His Majestie's Gunners and Engineers. A very curious and entertaining old work on ordnance, printed in London in 1628. Presented by Alfred H. Cowles, Lockport, N. Y.

# BIBLIOGRAPHIC NOTES.

**ANNALEN DER HYDROGRAPHIE UND MARITIMEN METEOROLOGIE.**

15TH ANNUAL SERIES, 1887, No. 4. Observations for the magnetism of the earth by the International Polar Expeditions. Report of a reconnaissance on the east coast of Africa, made by H. I. M. gunboat Hyäne. The rivers Malimba and Benudo, west coast of Africa. Deep-sea soundings in the Arabian Gulf, U. S. S. Essex. Currents in the Indian Ocean, observed by H. I. M. ships Sophie, Carola, and Bismarck. Report on the voyage of the German brig Nicolaus from Liverpool to Banana, thence via West Indies to Kopenhagen. Remarks about Tamarindo and Corinto, on the Pacific coast of Central America. Voyage of the Danish cruiser Fylla to Baffins Bay, 1886. Geographical positions of different parts of the world. Two hurricanes in the northwestern part of the Pacific Ocean off Japan. Weather chart of the North Atlantic Ocean. Short Notices: Regulations for the navigation of the Suez Canal by night. Tides in Finsch Harbor, Kaiser Wilhelm's Land. Remarks about several islands of the Ellice group, Gilbert group, Union group, and Phoenix group. Entrance to Palaevan, Island of Mindora Fusan, east coast of Corea. Inland passage between Amoy and the river Min. Vladivostock. Karsakowsk, south end of the island of Saghalien. Kaan Island, South Pacific Ocean. Bottle-post.

No. 5. Samana Bay, San Domingo. Description of the coast of Kaiser Wilhelm's Land. Nimrod Sound, China. Distribution of the temperature of the water at the surface of the ocean. Determination of the position and characteristics of islands and reefs in the ocean. Cyclones in the Gulf of Bengal. Hurricanes and gales in the South Pacific Ocean in the vicinity of Easter Island. Rain of ashes in New Guinea. Short Notices: Mouth of the river Congo. West coast of Africa, near Cape Negro and Cape Albino. Wood's Hull, east coast of the United States. Mayaguez, Porto Rico. Ras al Khyle, east coast of Africa. Currents and surface temperatures in Formosa Straits. Harbor of Hiute, Gulf of Anend, Chiloe, east coast of Chile. Remarks about several islands of the Panmotu archipelago. Bottle-post.

No. 6. The influence of the rotation of the sun on the magnetism of the earth. Sailing directions and descriptions on the east coast of Africa. Remarks about the Solomon Islands. Christmas Island in

the Indian Ocean. Navigation about Cape Gordafin during the S.W. monsoon. Frequency of storms near the times of equinox. March typhoons in Japan. Upper air currents near the equator. Short Notices: Sailing directions for leaving St. Paul de Luando. Soundings on the bar of Maracaibo. Currents on the east coast of Africa between Zanzibar and Capetown. Port Phaeton, Tahiti. Bottle-post.

No. 7. Quarterly review of the weather observations of the German Nautical Observatory, Fall of 1883. Hydrographic observations of H. I. M. S. Adler in Bismarck archipelago, Kaiser Wilhelm's Land, and the Anachoreten and Hermit Islands. Deep-sea soundings in the North Atlantic Ocean, U. S. S. Juniata. Deep-sea soundings in the Indian Ocean, U. S. S. Essex. Currents, ice, and navigation near the Coast Islands. Rains on the Island of Mauritius and adjacent parts of the ocean. Short Notices: Temperature and currents in the Corral Sea. Bottle-post.

No. 8. The use of oil to calm the sea: examples. Extracts from the log of the German bark Speculant, west coast of Central America. Deep-sea soundings in the Indian Ocean, H. M. S. Flying Fish. Quarterly review of weather observations of German Nautical Observatory, Fall of 1883: conclusion. Rain chart of the Atlantic and Indian Oceans. Chart of the division of the Indian Ocean into stations for the vessels observing for the German Nautical Observatory. Short Notices: Mossamedes, west coast of Africa. Bottle-post.

E. H. C. L.

BULLETIN OF THE AMERICAN IRON AND STEEL ASSOCIATION.

No. 22, June 29, 1887.

The steel stern-post for the cruiser Charleston was successfully cast on the 22d inst. by the Pacific Rolling Mill Co., at San Francisco. The post is 22 feet long on the keel, with an upright of 20 feet, and weighs about 15,000 pounds.

The Standard Steel Works at Thurlow, Pa., cast a steel stern-post for gunboat No. 1, weighing 15,000 pounds, and an engine bed-plate for the cruiser Baltimore.

W. F. W.

No. 24, July 13. Southern resources for the manufacture of iron and steel.

A paper by the editor, James M. Swank, giving a resumé of the progress of the Southern States in the manufacture of iron and steel since the war, and of the resources of Maryland, West Virginia, Tennessee, Alabama, North Carolina, and Georgia in the production of iron ore.

No. 25, July 20. Big guns gone off at Boston.

A description of the two immense 90-foot gun lathes and accompanying crane to be removed from the South Boston Iron Works to the Watervliet Arsenal.

Production of pig iron and steel in the first half of 1887.

No. 26, July 27. Three valuable statistical iron and

NO. 27, AUGUST 3 and 10. The iron industry of the Basque Provinces. Relation of the iron industry of the South to that of the country at large.

NO. 28, AUGUST 17. Prices of iron and steel from 1885 to 1887.

Giving a table of the monthly range of prices for the eight leading products from January, 1885 to August, 1887, averaged from weekly quotations.

NO. 29, AUGUST 24. Important financial operations in the new Northwestern iron ore fields.

A description of the large companies formed for the purpose of mining the new Northwestern ore fields.

NO. 30, AUGUST 31. The Bethlehem gun and armor contracts.

An explanation of the report that foreign aid has been sought by the Bethlehem Iron Co. in its fulfillment of the contract to furnish guns and armor for the Government.

NO. 31, SEPTEMBER 7. Sketch of the late Alfred Krupp.

A translation by Joseph Wharton of an obituary article in the August number of the *Stahl und Eisen.*

NO. 33, SEPTEMBER 21. Iron and steel imports for July and August.

A summary in tabular form of the imports of iron and steel into the United States from all countries.

NO. 35, OCTOBER 5. An electrical street car.

An electrical motor applied to a street car has been successfully tested in Philadelphia. The storage batteries are placed under the seat in one corner of the car, and are said to be able to run the car for four hours. The power thus obtained is said to be cheaper than either horse or cable power.

NO. 36, OCTOBER 12. Our iron and steel imports in August.

Tabulated from the monthly summary of the Bureau of Statistics, Treasury Department.

NO. 38, OCTOBER 26. Importing a million tons of British iron and steel in nine months.

The import of steel rails amounted alone to 135,621 tons; of pig iron, 331,326 tons; of unwrought steel to 183,210 tons. The exports of iron and steel from Great Britain to all countries, from the first of the year to October 1, amounted to 3,104,131 tons. C. R. M.

COMPTE RENDU DES TRAVAUX DE LA SOCIÉTÉ DES INGÉNIEURS CIVILS.

JANUARY, 1887.

This number contains a very interesting paper, by M. Cabanallas, on the application of electricity to the transportation and distribution of energy; also, an exhaustive mathematical study of the efficiency of various forms of dynamos and the special advantages of each for different purposes. The conclusions to be drawn from this paper point to a steady advancement in the advantages to be gained by the employment of electricity as a mode of transmission of energy, and to an increase in the degree of excellence of machines for its production. As its advantages are made more apparent, the forms of

motors needed for reconversion of electrical energy into mechanical work will become more numerous, causing an increasing field for the inventor during the next few years, and stimulating to activity and perfection the companies now in the market.

JUNE, 1887.

Under the Notes in this number a new method for the production of sodium is described. It has been employed advantageously by a company formed in London, and promises to make it possible to separate this metal from its carbonates by a comparatively cheap process. The price will, it is said, become about 25 cents a pound. With the reduced price of sodium it will be possible to procure both aluminium and magnesium at very much lower rates, causing thereby a diminution in the cost of Mitis steel. S. M.

ENGINEER.

JUNE 3, 1887. The submarine torpedo boat Nordenfeldt.

Account of trial on 26th May of the fourth and largest submarine boat built by Nordenfeldt. She is 125 feet long, and when immersed displaces 245 tons. I. H. P. 1200.

JUNE 10. The Italian cruiser Dogali.

Length over all, 267 feet; length between perpendiculars, 250 feet; breadth moulded, 37 feet; depth moulded, 20 feet 6 inches; draught of water forward, 12 feet; draught of water aft, 16 feet; draught of water, mean, 14 feet 6 incl displacement, 2050 tons; indicated horse power, natural draught, 5000; forced draught, 7700; speed, forced draught, 19.66 knots. Armament, six 6 breech-loading guns on centre pivot, Vavasseur mountings; nine 6-p rapid-fire guns on recoil carriages; six Gardner guns; one bow torpedo fixed; one stern torpedo gun, training; two broadside training torpedo

The vessel has twin screws, each propeller being driven by a triple sion horizontal direct-acting engine. Storage is provided for coal, which would serve at maximum speed for a run of about 1100 knots, or at half speed for about twenty days or 4500 knots. is rigged with two military masts, with light fore and aft sails. arranged as revolving towers, completely hiding the gunners. Each one Gatling gun. The whole length of the hold of the vessel from st is protected by a steel deck of a minimum thickness of 1 inch and of 2 inches. The vessel carries two search lights of 20,000 can complete outfit of internal lighting. This vessel is the first war triple expansion engines. Diameter of cylinders 30, 45, and 73 2 feet 9 inches. Marshall's valve gear. Propeller three bladed. Inde pumps. Condensers of brass. There are four boilers, each with Blower, driven by Brotherhood engines. Engines in separate water rooms, with doors moving horizontally, worked from deck. in two water-tight stoke holes. On trial the engines worked w lutions, 7600 I. H. P., and speed 19.66 knots.

JUNE 24. The Nordenfeldt submarine boat at C

On the 7th June No. 2 boat was tried for five hours at Co steaming at surface and below, running for two hours of the ti stored in the reserve boiler and had 90 pounds pressure at she could have gone on longer.

AUGUST 5. The engines of the Dogali (Italian cru r).

AUGUST 12. H. M. S. Trafalgar (illustrated). I (illustrated).

AUGUST 19. The management of marine boilers: editorial.

In the English merchant marine great difficulty is found in preventing rapid corrosion of boilers. In the Navy this is obviated by using open tanks to collect the feed water and allow all air to escape. The feed pump is arranged to pump only "solid" water, and care is taken when suspending zinc plates in the boiler to secure perfect metallic connection.

An improved water gauge float.

AUGUST 26. The use of petroleum fuel. Marine engines from a shipowner's point of view. Petroleum refuse as a fuel: editorial. Cost of transmission of power by electricity, water pressure, compressed air, and ropes.

SEPTEMBER 2. Steel faced armor; trials in Russia (illustrated).

SEPTEMBER 9. Experiments on the mechanical equivalent of heat on a large scale.

The result showed that the mechanical equivalent of heat is 769 instead of 772, as found by Joule. The difference is ascribed to the fact that in the apparatus used all losses of heat were prevented, no losses had to be calculated, and the specific heat of the apparatus did not enter into calculation, as it was kept at a practically normal temperature throughout. W. F. W.

ENGINEERING.

JULY 1, 1887. The "Brennan" torpedo (concluded). Hydro-pneumatic disappearing gun carriages at the Newcastle Exhibition. Defects in the designs of war ships.

JULY 15.

H. M. S. Undaunted, a belted cruiser, recently had a four hours' forced draught trial loaded down to the water line. Draught forward 20 feet, aft 22 feet; total I. H. P. developed 8602. Speed on measured mile 19.4 knots, the highest yet attained by any English heavily armed ship of war.

The Board of Admiralty are of opinion that the dockyards should build the great bulk of the ships required for the Navy, and this year, out of thirteen ships required, eleven will be so built.

The Spanish torpedo boat Ariete, on trial, steamed a short time at the rate of 26 knots. A peculiar feature is the "pipe" boiler, a development of the Herreshoff boiler, and considered by the designer, Mr. Thornycroft, an improvement.

JULY 22. The Impérieuse.

The general conclusion derived from an experimental cruise was that the ship was a successful war ship, but would be improved by removing her masts entirely.

Dr. Gustaf de Laval's new submarine boat. Thornycroft's water-tube boiler (used on the Spanish boat Ariete).

JULY 29. Progress and development of the marine engine.

AUGUST 5. Progress and development of the marine engine.

Abstract from paper read before the Institution of Naval Architects.

AUGUST 12. Progress and development of the marine engine: discussion.

AUGUST 19. The engines of the Nicolas I. Illustrated.

Triple expansion engines arranged so that the L. P. cylinder is easily thrown out of use when working at reduced power.

AUGUST 26. Liquid fuel for locomotives: editorial.

SEPTEMBER 2.

A twin-screw steel torpedo gunboat named the Grasshopper, and of 450 tons displacement, has been launched. She will have engines of 3000 I. H. P., speed 19 knots, and carry one 4-inch steel B. L. and six 3-pounder rapid-fire guns, and three torpedo tubes.

SEPTEMBER 23.

From experiments made in Portsmouth Dockyard on the variation in the resistance of metals with an increase in temperature, it appears that the strength of iron increases uniformly up to 500° F., but the ductility diminishes up to about 300° F., after which it increases again till a somewhat higher temperature is reached, and thence remains nearly constant up to a temperature of 500° F. Steel tested in a similar way showed no deterioration in strength up to the highest temperature named, but at this point its ductility was diminished one half.

H. M. S. Trafalgar.

The Trafalgar was launched at Portsmouth, and is the last great armor-clad which it is proposed to build. She is the largest and most formidable battle-ship ever constructed in this country (England), and is larger than either the Admiral Baudin or the Formidable of France, although inferior in displacement to some of the armor-clads of Italy. She may be said to represent the most perfect protection by means of armor against the power of a gun at a time when it is seriously contemplated to abandon armor. The following are some particulars: Length, 345 feet; breadth, 73 feet; mean draught, 27 feet 6 inches; displacement, 12,000 tons; thickness of armor at water line, 14 inches and 20 inches (steel faced); thickness of armor on turrets, 18 inches (steel faced); height of armor above water, 11 feet; engine power, 10,500 I. H. P.; speed, 16.5 knots; bunker capacity, 900 tons; principal armament, four 67-ton B. L. R.; weight of projectile, 1250 pounds; weight of charge, 630 pounds; cost of hull and machinery, £800,000. Hydraulic power is used for working the large guns and many of the auxiliary engines. The ship can steam 5500 knots at 10 knots per hour, or 1050 knots at 16½ knots per hour.

Armored ships. Interesting letter from Sir E. J. Reed.

SEPTEMBER 30. Steam pipe explosion on board the S. S. Elbe.

W. F. W.

JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIET

JULY. The use of pairs of circumpolar stars for fin meridian.

An article describing a method available on land for finding when the time is not accurately known.

Weights and measures.

A report of a committee of the Boston Society of Civil
on showing progress in the extension of the metric sys
to secure its adoption in the United States.

JOURNAL DU MATELOT.

OCTOBER 15, 1887. Turn-abouts and vidette boats.

OCTOBER 22. Several experiences in using oil in storms: the passenger steamers Abd-el-Kader in the harbor of Sfax, and the Manoubia in the roads of Mostaganem. D. H. M.

JOURNAL OF THE FRANKLIN INSTITUTE.

VOLUME CXXIV., No. 739. The use of oil for stilling waves: with a description of a new oil distributor for the use of mariners.

This distributor, which is the invention of T. F. Townsend, Philadelphia, consists of a hollow metal globe, ten inches in diameter, with a capacity of one and a half gallons. It has an air chamber to float it in an upright position, and two valves to regulate the flow of the contents.

No. 740. A simplification of the new weather signal code. The reaction of a liquid jet.

No. 741. On anemometers.

No. 742. Improvement of tidal rivers. Was Philip Reis the inventor of the articulating telephone? Pyro-magnetic motors and generators of electricity.

At a recent meeting of the American Association for the Advancement of Science, Mr. Thomas A. Edison called the attention of the public to a very ingenious device, by means of which he has been able to convert the heat of coal or gas into electric currents by means of magnetism. The machine consists of a core of soft iron made of sheet metal, having a thickness of .002 of an inch, and rolled so as to permit hot gases to pass between the sheets. This core is surrounded by a coil of wire, and while the core is in a strong magnetic field it is alternately heated and cooled, thus inducing currents in the coil. It is found, however, that the rapid oxidation and disintegration of the thin metal presents a serious difficulty.

No. 743. Improvement of the port of Philadelphia. Description of an improved triple-expansion engine. J. H. G.

JOURNAL OF THE MILITARY SERVICE INSTITUTION.

JUNE, 1887.

Lieutenant E. L. Zalinski contributes a very interesting and instructive article on the pneumatic dynamite torpedo gun, under the following heads: (1) Evolution and development of the machine. (2) Accuracy of fire. (3) Use for coast defense. (4) Counter-mining. (5) Use against torpedo boats, dirigible torpedoes, and submarine boats. (6) Use as an adjunct when ships attempt ramming. (7) Torpedo rams. J. H. G.

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION.

VOLUME XXXI., No. 140. Accuracy of artillery fire. Alterations lately made in H. M. S. Ajax, illustrating the truthfulness of the results obtained by experiments on her model in the tank at Torquay. Coaling ships of war at sea. The interior economy of a modern fleet.

THE RAILROAD AND ENGINEERING JOURNAL.

AUGUST, 1887. Quadruple-expansion marine engines. High pressure marine boilers. The new naval vessels. Hydro-pneumatic disappearing gun carriage.

Sir W. G. Armstrong, Mitchell & Co., Elswick, England, are the makers of a new disappearing gun carriage. The recoil is utilized for compressing air in a chamber of the recoil cylinder, by means of water or other fluid which is forced from the outer chamber through a valve into the air chamber. At the same time the movement of the piston in the cylinder is communicated, by means of a cross-head, to a pair of elevating levers, in the upper ends of which the gun trunnions are carried, the lower ends being connected to the gun carriage. After loading, the compressed air is utilized for raising the gun.

SEPTEMBER. The new war ships. The English naval review. Fighting ships. The new yacht Volunteer.

OCTOBER. The increase of the American navy. Engravings of the English ironclad Trafalgar, and of the English 67-ton gun.

NOVEMBER. Lieutenant Bradley A. Fiske, U. S. N., contributes a continued article, "How Electricity is Made." J. H. G.

MINUTES OF PROCEEDINGS OF THE INSTITUTION OF CIVIL ENGINEERS. VOL. XC., 1886-1887. PART IV.

Selected papers No. 218.

The Use of Cast Steel in Locomotive Engines, by John Alfred Hill, Wh. Sc. Stud. C. E., gives the details for which cast steel can be conveniently and economically applied in the construction of locomotives, together with tables (I.) showing how the strength of steel castings is affected by their chemical composition, (II.) the effect of annealing, and (III.) the result obtained from testing six specimens, two being cast steel, two forged steel, and two forged iron.

Selected paper No. 227.

Platt and Hayward, on Strength of Iron and Steel, give experiments on the strength of iron and steel in shear and torsion.

Foreign abstracts: A volumetric method of estimating the carbon in iron, by J. Wiborgh.

The novelty of this process consists in the direct measur[illegible] carbonic acid produced from the oxidation of the carbon in the [illegible] investigation, instead of weighing it as potassium carbonate, as is

Electric time signalling on the German coast, by Pr[illegible] Förster.

MITTHEILUNGEN AUS DEM GEBIETE DES SEEWESENS.

VOL. XV., Nos. VII. and VIII. Night attacks [illegible]pe by Captain A. v. Becker. Use of hyperbolic functio[illegible] by Prof. E. Gelcich. Episodes from the history o[illegible] Corrosion of iron and steel ships, and their protec[illegible] (Institution of Naval Architects). French r[illegible]ula [illegible]nobile torpedoes. Minor notes from for[illegible] perio[illegible]

No. IX. Photographic determination of the disturbance of air produced by shot,* by Prof. P. Salcher. Parson turbo-electricity generator (from Engineering). Use of submarine boats in war. The latest mechanical methods for drawing stability curves of vessels. Notes from foreign magazines.

No. X. Progress in the development of the marine steam engine (from English articles). Experiments for finding the relative conductivity of boiler deposits, by M. Burstyn. The gunboat as a factor in coast defense, by Admiral Sir Geo. Elliot. Notes from foreign magazines.
E. H. C. L.

## PROCEEDINGS OF THE ROYAL ARTILLERY INSTITUTION.

MAY, 1887. Artillery fired from railway wagons.

Details of experiments with 40-pounder B. L. R. on railroad trucks or Indian metre-gauge road.

JUNE. Remarks on high-angle and direct fire from coast batteries, by Col. G. A. Crawford, late R. A.

"I think we may conclude that to fire high-angle shells at a modern ironclad will be a thorough waste of ammunition, as well as a waste of *personnel* in employing gunners to man them in our coast batteries. On the other hand, if ships of war attacking earth forts were armed with a complement of howitzers, their high-angle fire against elevated forts would be very annoying and disturbing both to the forts and to the gun detachments; in fact, it is the only sort of artillery fire that could touch the fort. Howitzers therefore might be suitable weapons for our ships."

Direct fire.

"The proper weapons for our modern coast batteries are: *guns, heavy, medium, quick-firing* and *machine guns*, and the projectiles to be fired from them are: *armor-piercing, shrapnel* and *case*; the proportion being—65 per cent armor-piercing, 20 per cent shrapnel, 15 per cent case. Since the introduction of our new B. L. guns, the range for piercing armor has increased to 4000 yards, and even longer when firing at thinly clad ships; and the scattered gun system, with guns mounted at elevations of two, three, four, or even five hundred feet above the sea, gives the fort numerous advantages both in attack and defense. The ship becomes much longer under fire. A concentrated fire can be brought to bear on it. A deck fire from elevated sites is obtained. And for defense, the greater the altitude of the fort the safer it is from a ship's fire.

"In harbor defense, we may safely conclude that an enemy's ship will not attempt to anchor, so that the target we shall have to fire at will always be a moving target. I have come to the conclusion that with well trained gunners it is as easy to hit a ship in motion as a ship at anchor."

Partial details of the experiments and practice at high angle and direct firing, on which these conclusions are based, are given.

The French troops in Algeria, by Captain E. Lambart, R. A.

From this a few good hints in regard to the physical training of soldiers might be obtained. Of no interest to naval reader.

* This article being such a valuable addition to the literature of ordnance, a full translation of it will be published in the next number of our Proceedings.

Should a piston packing ring be of the same thickness at every point? by L. H. Rutherford and F. R. Hutton. Notes for discussion in relation to the development of the compound engine, and the probable limit of steam pressure in marine engines and boilers, by Chas. E. Emery. Notes for discussion on cylinder condensation, and the reduction of the same by the use of the compound engine, by Chas. E. Emery. What are the needs of our Navy? by Ramsay H. Ashton. Our coast defense, its cost, and its mechanical problems, by Joseph Morgan, Jr.

Reviewed at length in the Professional Notes of the present number of our Proceedings.

Steam and power; the commercial determination of its cost, by Henry R. Towne. C. R. M.

UNITED SERVICE GAZETTE.

JULY 2, 1887. An article on navy guns.

JULY 9. P. 547: Description of the Undaunted.

JULY 16. P. 566: Trial trip of the Undaunted.

JULY 23. Quick's breechloading ordnance.

AUGUST 6. Spanish torpedo boat Ariete; also Thornyc tube boiler, giving plans of boat and boiler.

AUGUST 13. Admiral Sir George Elliot on English c

AUGUST 27. Bland's patent diamond sight.

SEPTEMBER 3. The electric lighthouse on the Isle of May, ings and description.

SEPTEMBER 17. Firing with the "fixed sight" by a well known expert). Australian naval defense.

SEPTEMBER 24. Reorganization of English War Office. lighting of barracks. Launch and description of Trafalgar.

OCTOBER 8. The rifles of modern armies.

OCTOBER 15. Trial of the new Spanish war ship on the Clyde. The Gioto, a new torpedo cruiser navy. Steam trials of the English vessels Australia and F

OCTOBER 22. Indirect musketry firing. The Mete torpedo cruiser afloat, constructed by Schichau at Elbi Austrian navy; speed, 23.1 knots per hour. L. h.

LE YACHT.

JULY 9, 1887. P. 254: Triple expansion engines.

JULY 16. P. 259: Proof trial of an armor target, l of the armor intended for the Iver-Hvitfelt of the

P. 262: View of English torpedo boat Fearless. Accidents to the boilers of English torpedo boat No. 47.

JULY 23. P. 267: The defects of torpedo boats. P. 269: The manœuvres of the French squadron. The cruising torpedo boat Faucon. P. 271: An article on the English navy by E. Weyl. P. 272: Plans and description of Brennan's movable torpedo. P. 273: View of Italian cruiser Dogali.

JULY 30. P. 285: Plan and description of apparatus for throwing oil on water during a storm.

AUGUST 6. P. 298: The Spanish navy.

AUGUST 13. P. 306: The Spanish navy (continued).

AUGUST 20. P. 311: Modifications to the rules of the road—to prevent collisions. P. 316: An experiment on the application of electricity for moving steamers. Transportation of a torpedo boat by rail—views of boat and carriages.

AUGUST 27. P. 323: The Spanish navy (concluded).

SEPTEMBER 10. P. 340: Plan and description of the Trafalgar. P. 342: View and description of German gunboat Eber.

SEPTEMBER 17. P. 349: Plans of Spanish torpedo boat Ariete (to go with article in Le Yacht of August 13, 1887). P. 348: Two letters on means of preventing collisions in fog.

SEPTEMBER 24. P. 355: The subject of collisions considered by E. Weyl. P. 357: Projects for protected cruisers of the 1st and 2d class in France.

OCTOBER 1. P. 365: Navigating in time of fog.

OCTOBER 15. P. 383: The personnel of the French reserve. P. 389: Picture of the English cruiser Mersey.

OCTOBER 22. P. 396: The currents among the Channel Islands (French).

D. H. M.

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## 1888.

**Elected at the regular annual meeting, held at Annapolis, Md., October 14, 1887.**

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# *SPECIAL NOTICE.*

## NAVAL INSTITUTE PRIZE ESSAY, 1888.

A prize of one hundred dollars and a gold medal is offered by the Naval Institute for the best Essay presented, subject to the following rules:

1. Competition for the Prize is open to all members, Regular, Life, Honorary, and Associate, and to all persons entitled to become members, provided such membership be completed before the submission of the Essay. Members whose dues are two years in arrears are not eligible to compete for the Prize until their dues are paid.

2. Each competitor must send his essay in a sealed envelope to the Secretary and Treasurer on or before January 1, 1888. The name of the writer shall not be given in this envelope, but instead thereof a motto. Accompanying the essay a separate sealed envelope will be sent to the Secretary and Treasurer, with the motto on the outside and writer's name and motto inside. This envelope is not to be opened until after the decision of the Judges.

3. The Judges shall be three gentlemen of eminent professional attainments (to be selected by the Board of Control), who will be requested to designate the essay worthy of the Prize, and, also, those deserving honorable mention, in the order of their merit.

4. The successful essay shall be published in the Proceedings of the Institute; and the essays of other competitors, receiving honorable mention, may be published also, at the discretion of the Board of Control; and no change shall be made in the text of any competitive essay, published in the Proceedings of the Institute, after it leaves the hands of the Judges.

5. Any essay not having received honorable mention, may be published also, at the discretion of the Board of Control, but only with the consent of the author.

6. The subject for the Prize Essay is, *Torpedoes.*
   - I. *Their place in naval warfare.*
   - II. *Character of the torpedoes and torpedo vessels required for the naval service of the United States.*
   - III. *Organisation of our naval torpedo service and instruction of its personnel.*
   - IV. *Tactics to be employed in offensive and in defensive warfare.*

7. The essay is limited to fifty printed pages of the Proceedings of the Institute.

8. The successful competitor will be made a Life Member of the Institute.

9. In the event of the Prize being awarded to the winner of a previous year, a gold clasp, suitably engraved, will be given in lieu of a gold medal.

By direction of Board of Control.

CHARLES R. MILES,
*Lieut., U. S. N., Secretary and Treasurer.*

ANNAPOLIS, MD., *January 1, 1887.*

# APPENDIX.

Vol. XIII., 1887.

# UNITED STATES NAVAL INSTITUTE.

## 1873-1887.

## ORIGIN, PROGRESS, AND OBJECT.

### HISTORICAL.

The inaugural meeting of the Institute was held October 9, 1873, at which Rear-Admiral John L. Worden, U. S. N., presided, and the late Commodore Foxhall A. Parker, U. S. N., read a paper entitled "The Battle of Lepanto." The object of the association as then stated was for the advancement of professional and scientific knowledge in the Navy by affording a medium for the free interchange of serious thought and the debate of important subjects concerning naval science and practice. In 1874 a Constitution was adopted and the membership increased to seventy-five. The first volume, entitled "The Papers and Proceedings of the United States Naval Institute," appeared in 1875. During the succeeding few years the Institute grew in membership and in the estimation of the Army and Navy, and by the adoption of the Constitution of June 2, 1884, it took a firmer hold and marked out its future success. At present its membership is as follows—viz. Honorary members, 7; life members, 75; regular members, 575; associate members, 130.

In addition to its membership the Institute has a large number of subscribers and exchanges, so that now the published quarterly edition numbers 1350 copies.

Since its organization the field of usefulness of the association has become enlarged, and besides the first object, already mentioned, its work includes the following:

1st. By means of the large number of associate members, comprising Army officers, those of the Revenue Marine, naval architects of distinction, consulting and mechanical engineers of high standing, and the leading manufacturers of steel and other material for the Navy, it promotes good feeling and mental stimulation, which are broadening and beneficial to all parties.

2d. Its members and subscribers, including libraries and colleges, disseminate important authentic information relating to naval science and to the subject of national defense.

3d. The Professional and Bibliographic Notes furnish a compendium of valuable information, taken from home and foreign sources, to which most members have not access.

4th. The publications of the Institute become a repository for important historical records concerning the naval service, as well as for valuable reports of experiments in a form convenient for reference.

## PUBLICATIONS.

"Quarterly, or as much oftener as the Board of Control may decide," the Proceedings are published, and one copy is mailed to every member. Up to the present time forty (40) numbers have been issued, the contents of which may be seen in Table of Contents as published in this catalogue. Full sets may be obtained from the Institute by application to the Secretary and Treasurer.

## GENERAL INFORMATION.

*Membership.*—Under the Constitution (Article VII.) the active members of the Institute are divided into three classes, styled respectively: Regular, Life, and Associate Members. The provisions for Honorary Membership are embodied in Section 4, Article VII.

Officers of the Navy, Marine Corps, and all civil officers attached to the naval service are entitled to become regular or life members, without ballot, on payment of dues or fees to the Secretary and Treasurer, or to the Corresponding Secretary of a Branch. The Prize Essayist of each year becomes a life member without payment of fee.

Associate members are elected from officers of the Army, U. S. Revenue Marine, foreign officers of the naval and military professions, and from persons in civil life that are interested in the purposes of the Institute. Associate members not to exceed one hundred (100) may be elected to life membership. Section 7, Article VII., Constitution gives manner of election of associate members.

For information on any subject of business with the Institute, address the Secretary and Treasurer, U. S. Naval Institute, Annapolis, Md.

## DUES, FEES, SUBSCRIPTION.

initiation fee is required. Regular and associate members pay
oining the Institute, and upon the first day of each succeeding

January. Life members pay $30 in lieu of all dues, which sum is invested with the Reserve Fund and held in perpetuity, to guarantee the future interests of such members.

When a member becomes in arrears for more than one year, sending the publications to him is discontinued. Every person admitted to membership is considered as belonging to the Institute, and liable for the payment of dues until he shall have informed the Secretary and Treasurer at Annapolis, Md., of his desire to withdraw, when, if his dues have been fully paid, his name shall be erased from the list of members.

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Moses, F. J. 2d Lt. U. S. M. C.
Much, G. W. Naval Constructor
Mullany, J. R. M. Rear-Admiral
Mullett, T. B. Capt. U. S. R. M.
Munroe, C. E., Chemist, U. S. Torpedo Corps
Murdock, J. B. Lieutenant
Muse, W. S. Capt. U. S. M. C.
Nazro, A. P. Lieutenant
Nelson, H. C. Med. Inspector (ret.
Nelson, V. S. Ensign
Newcomb, S., Professor, Superintendent Nautical Almanac
Newell, J. S. Lieut.-Commander
Niblack, A. P. Ensign
Nichols, F. W. Lieutenant
Nichols, H. E. Lieut.-Commander
Nichols, S. W. Commander
Nicholson, R. F. Lieutenant
Nickels, J. A. H. Lieutenant
Nicoll, W. L. Chief Engineer
Niles, N. E. Lieutenant
Nixon, L. Asst. Naval Const'r
Noel, J. E. Lieut.-Commander
Norris, G. A. Lieut.-Commander
Norton, C. F. Lieutenant
Norton, C. S. Captain
Norton, H. P. Asst. Engineer
O'Neil, C. Commander
Osterhaus, Hugo Lieutenant
Paine, S. C. Lieutenant
Parker, James, New York
Parker, J. F. Lieutenant
Parker, J. P. Ensign
Parks, W. M. P.-Asst. Engineer
Parmenter, H. E. Ensign
Patch, N. J. K. Lieutenant
Pearson, F. New York
Peary, R. E. Civil Engineer
Peck, G. Medical Director
Peck, R. G. Lieutenant
Pegram, J. C. Providence
Pendleton, E. C. Lieutenant
Perkins, H. Lieutenant
Perry, Thos. Lieut.-Commander
Phelps, T. S. Rear-Admiral
Picking, H. F. Commander
Pillsbury, J. E. Lieutenant
Plunkett, C. P. Ensign
Poe, C. C. Naval Cadet
Pook, S. H. Naval Constructor
Porter, Theodoric, Lieutenant
Potter, W. P. Lieutenant
Potts, T. M. Lieutenant
Poundstone, H. C. Ensign
Poyer, J. M. Ensign
Prime, E. S. Lieutenant
Prindle, F. C. Civil Engineer
Qualtrough, E. F. Lieutenant

Rae, C. W. P.-Asst. Engineer
Ramsay, F. M. Captain
Read, J. J. Commander
Reeder, W. H. Lieutenant
Rees, C. P. Lieutenant
Reisinger, W. W., Lieut.-Commander
Remey, G. C. Captain
Remey, W. B. Judge Adv.-General
Reynolds, E. L. New York
Rhoades, W. W., Lieut.-Commander
Rice, John Minot, S. B., Ph. D., Professor, U. S. Navy
Rittenhouse, H. O. Lieutenant
Robeson, H. B. Commander
Robie, E. D. Chief Engineer
Robinson, L. W. Chief Engineer
Rodgers, C. R. P. Rear-Admiral
Rodgers, F. Commander
Rodgers, J. A. Lieutenant
Rodgers, Raymond P., Lieutenant, In charge N. I. Office
Rodgers, T. S. Ensign
Rodgers, W. L. Ensign
Roelker, C. R. P.-Asst. Engineer
Rogers, C. C. Lieutenant
Roller, J. E. Lieutenant
Rooney, W. R. A. Lieutenant
Roosevelt, N. L. New York
Roper, Jesse M. Lieutenant
Ross, A. Lieutenant
Rowan, S. C. Vice-Admiral
Rush, R. Lieutenant
Russell, J. H., Rear-Admiral (ret.)
Rust, Armistead, Naval Cadet
Ryan, T. W. Ensign
Safford, W. E. Ensign
Salter, T. G. C. Lieutenant
Sampson, W. T., Commander, Superintendent U. S. Naval Academy
Sargent, N. Lieutenant
Savage, Thos. Boatswain
Sawyer, F. E. Lieutenant
Schaefer, H. W. Lieutenant
Schley, W. S., Commander, Chief of Bur. of Equipment and Recruiting
Schouler, J. Commander
Sebree, U. Lieutenant
Selfridge, J. R. Lieutenant
Semple, Lorenzo, Ensign
Sharp, A. Lieutenant
Sharrer, W. O. Lieutenant
Shearman, John A. Lieutenant
Shepard, E. M. Commander
Shoemaker, W. R. Ensign
Sicard, M., Captain, Chief of Bureau of Ordnance
Sigsbee, C. D. Commander
Simpson, E. Rear-Admiral (ret.)
Simpson, E. Ensign
Singer, F. Lieutenant
Skerrett, J. S. Captain
Sloan, R. S. Oswego, N. Y.
Smith, J. T. Lieutenant
Smith, R. Campbell, Ensign
Smith, S. F., St. Paul's School, Concord, N. H.
Smith, W. D. Chief Engineer
Smith, W. S. Asst. Engineer
Snow, A. S. Lieut.-Commander
Snyder, H. L. Chief Engineer
Soley, J. C. Lieutenant (retired)
Soley, J. R. Professor
Southerland, W. H. H. Lieutenant
Speel, J. N. P.-Asst. Paymaster
Sperry, C. S. Lieut.-Commander
Speyers, A. B. Lieutenant
Sprague, F. J. New York
Stahl, A. W. Asst. Engineer
Stanton, J. R. P.-Asst. Paymaster
Stanton, O. F. Captain
Stanworth, C. S. Naval Cadet
Staunton, S. A. Lieutenant
Stevens, T. H. Rear-Admiral
Stevens, T. H. Lieutenant
Stevenson, H. N., P.-Asst. Engineer
Stewart, R., Jr. Cadet Engineer
Stirling, Yates, Commander
Stockton, C. H. Lieut.-Commander
Stoney, G. M. Lieutenant
Stout, G. C.

Street, G. W. Ensign
Strong, E. T. Lieut.-Commander
Strong, W. C. Lieutenant
Sturdy, E. W. Lieutenant
Sutphen, E. W. Naval Cadet
Swinburne, Wm. T. Lieut.-Com.
Talcott, C. G. Asst. Engineer
Tallman, C. E. Sailmaker
Taussig, E. D. Lieutenant
Taylor, D. W. Asst. Naval Constr.
Taylor, H. C. Commander
Terry, N. M., A. M., Ph. D., Professor, U. S. N. A.
Terry, S. W. Commander
Thackara, A. M. Philadelphia
Thomas, C. Lieutenant
Tilley, B. F. Lieutenant
Tilton, McL. Capt. U. S. M. C.
Todd, C. C. Lieut.-Commander
Totten, G. M. Lieut.-Commander
Train, C. J. Commander
Turnbull, F. Lieutenant (retired)
Turner, T. J. Medical Director
Turner, W. H. Lieutenant
Tyler, G. W. Lieutenant
Underwood, E. B. Lieutenant
Varney, W. H. Naval Constructor
Veeder, T. E. D. W. Lieutenant
Vreeland, C. E. Lieutenant
Wadhams, A. V. Lieutenant
Wadsworth, H. Boston
Wainwright, Richard, Lieutenant
Walker, Asa, Lieut.-Commander
Walker, J. G., Captain, Chief of Bureau of Navigation
Warburton, E. T. Asst. Engineer
Waring, H. S. Lieutenant
Watson, E. W. Lieut.-Commander
Weaver, W. D. Asst. Engineer
Webb, T. E. Naval Constructor
Wells, C. H. Rear-Admiral (ret.)
Wells, Roger, Jr. Ensign
West, C. H. Lieutenant
White, E. Commander
White, W. P. Ensign
Whitham, J. M. Fayetteville, Ark.
Whittelsey, Wm. B. Ensign
Wilner, F. A. Lieutenant
Wilson, Byron, Captain
Wilson, F. A. Chief Engineer
Wilson, J. C. Lieutenant
Wilson, T. D. Chief Constructor
Winder, William, Lieutenant
Windsor, W. A. P.-Asst. Engineer
Winn, J. K. Lieut.-Commander
Winslow, F. Lieutenant
Winterhalter, A. G. Lieutenant
Wirt, W. E.
Wise, F. M. Lieutenant
Wise, Wm. C. Commander
Wolcott, C. C. Civil Engineer
Wood, E. P. Lieutenant
Wood, S. S. Ensign
Wood, W. M. Lieutenant
Woodbridge, W. E. Washington
Woodward, J. J., Asst. Naval Constr.
Woodworth, S. E. Ensign
Wooster, L. W. P.-Asst. Engineer
Worden, J. L. Rear-Admiral (ret.)
Worthington, W. F., P.-Asst. Engineer
Wright, M. F. Lieutenant
Yates, A. R. Captain

## ASSOCIATE MEMBERS.—130.

Abbot, F. V., First Lieutenant Engineers, U. S. A.
Angstrom, A., C. E., Torpedo Corps.
Azoy, Anastasio, C. M., New York.
Babcock, W. T., New York.
Balbach, E., Jr., 233 River street, Newark, N. J.
Balch, G. T., Colonel, Commissioner of Accounts, New York.
Barr, F., Captain, U. S. R. M.

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Hoffman, J. W., 208 S. 4th street, Philadelphia.
Hughes, R. P., Lieut.-Col., U. S. A., Insp'r-Gen'l, Presidio, San Francisco, Cal.
Humphrey, E. W. C., 412 Centre street, Louisville, Ky.
Hunt, W. P., President South Boston Iron Works, Boston.
Hyde, Marcus D., 623 Commercial street, San Francisco, Cal.
Ingalls, J. M., Captain First Artillery, U. S. A.
James, Nathl. T., 401 California street, San Francisco, Cal.
Johnson, Isaac G., C. E., Steel Manufacturer, Spuyten Duyvil, N. Y.
Kennon, L. W. V., Second Lieutenant Sixth Infantry, U. S. A.
Kent, Wm., 26 Highland street, Jersey City, N. J.
Kittelle, Geo. W., The Crescent, Eureka Springs, Ark.
Knight, Albert B., Engineer and Surveyor, Butte City, Mon.
Krupp, Alfred, Essen, Germany. (Krupp Cast-Steel Works.)
Laureau, L. G., of Gordon, Stroebel & Laureau, 226 Walnut street, Philadelphia, Pa.
Leu, Fred., 68 West street, Greenpoint, L. I.
Lieb, Charles A., Lieb Machine Works, New York.
Loring, B. W., Owego, Tioga County, N. Y.
Lyon, Henry, M. D., 34 Monument Square, Charlestown, Mass.
Macomb, M. M., First Lieutenant Fourth Artillery, U. S. A.
Mann, H. F., Pittsburgh, Pa.
Martinez, M. J., M. E., 30 Courtlandt street, New York.
Marx, J. L., Lieutenant, R. N., Arle Bury, Arlesford-Hants, England.
McLoughlan, J., 2041 Fifth avenue, New York.
Michaelis, O. E., Captain, Ordnance Department, U. S. A.
Miller, H. W., Morristown, N. J.
Miller, P. P., 293 Court street, Buffalo, N. Y.
Millis, John, First Lieutenant Engineers, U. S. A.
Mullett, A. B., Architect, 2501 Pennsylvania avenue, Washington, D. C.
Myers, T. Bailey, New York.
Nordhoff, C., Alpine, N. J.
Norton, James A., County Auditor, Tiffin, O.
Oliver, Wm. Letts, Chemist, San Francisco, Cal.
Partridge, W. E., M. E., 294 Broadway, New York.
Payson, A. H., Captain Engineers, U. S. A.
Pierce, Frank H., Mt. Carmel, Conn.
Pollok, A., 635 F street N. W., Washington, D. C.
Powell, W. T., Navy Department, Washington, D. C.
Pratt, N. W., The Babcock & Wilcox Co., 30 Courtlandt street, New York.
Quinan, W. R., Manager California Powder Works, San Francisco.
Randolph, L. S., M. E., Fernandina, Fla.
Raymond, C. W., Colonel Engineers, U. S. A.
Roepper, C. W., The Solid Steel Co., Alliance, O.
Ropes, J. C., 99 Mt. Vernon street, Boston, Mass.
Russell, A. H., Captain Ordnance, U. S. A.
Saito, M., Lieutenant Imperial Japanese Navy.

Schneider, Henri, Au Creusot, Saône-et-Loire, France
Schuyler, M. Roosevelt, New York.
Scott, Irving M., Union Iron Works, San Francisco, C
Scudder, E. M., Attorney and Counsellor, 66 Wall stre
Sears, W. H., C. E., 35 Congress street, Boston, Mass.
See, Horace, Superintendent Engineer of Wm. Cramp &
Shaw, A. J., 10 Pallas street, Providence, R. I.
Simpson, J. M., Captain Chilian Navy.
Sloat, Geo. V., Chief Engineer Old Diminion S. S. Co
Smedburg, W. R., Brevet Lieutenant-Colonel, U. S. A
Sperry, Chas., M. E., Port Washington, L. I.
Stetson, Geo. R., M. E., New Bedford, Mass.
Stratton, E. Platt, Consulting Engineer, 38 Courtlandt
Stueler, Rudolph, 159 Front street, New York.
Taber, H. S., Captain Engineer Corps, U. S. A.
Taylor, Harry, Second Lieutenant Engineer Corps, U.
Towne, Henry R., Stamford, Conn.
Turtle, Thomas, Captain Engineer Corps, U. S. A.
Vanderbilt, A., 113 Wall street, New York.
Webber, W. O., Superintendent Lawrence Shops, Law
Wellman, S. T., Superintendent Otis Iron Works, Clev
West, Thos. D., Foreman Cuyahoga Foundry, Clevela
Wheeler, F. M., M. E., New York.
White, J. F., S. B., Buffalo Chemical Works, N. Y.
Willamov, G., Consul-General Russia, Bucharest, Rou
Williams, Albert, Principal Michigan State Mining Scl
Williams, W. B., Attorney and Counsellor, Newark, N
Wilson, A. E., Lieutenant Chilian Navy.
Wisser, J. P., First Lieutenant First Artillery, U. S. A.
Woodall, James, Shipbuilder, Baltimore, Md.
Yamanouchi, M., Lieutenant Imperial Japanese Na
Washington, D. C.
Zalinski, E. L., First Lieutenant 5th Artillery, U. S. A.

## MEMBERS DECEASED SINCE JA

Lieutenant Wm. A. Hadden, Jan. 19, 1886.
Lieut.-Commander Richard Cotts, Feb. 3, 188
Lieutenant H. J. Hunt, May 5, 1886.
Lieutenant H. T. Stockton, May 6, 1886.
Passed Asst. Engineer Luther R. Harvey, Ju
General Lloyd Aspinwall, New York.
Rear-Admiral E. T. Nichols, Oct. 12, 1886.
Herman Eckel, Cincinnati, O., November, 18
Commodore P. C. Johnson, Jan. 28, 1887.
Lieutenant F. M. Gardner, Jan. 28, 1887.
Captain E. P. Lull, March 5, 1887.

## CORRESPONDING SOCIETIES AND EXCHANGES.

UNITED STATES.

American Academy of Arts and Sciences, Boston, Mass.
American Chemical Journal, Johns Hopkins University, Baltimore, Md.
American Geographical Society, New York City.
American Institute of Mining Engineers, New York City.
American Iron and Steel Association, Philadelphia, Pa.
American Metrological Society, Columbia School of Mines, New York City.
American Philosophical Society, Philadelphia, Pa.
American Society of Civil Engineers, New York City.
American Society of Mechanical Engineers, New York City.
California Academy of Sciences, San Francisco.
Connecticut Academy of Arts and Sciences, New Haven, Conn.
Franklin Institute, Philadelphia, Pa.
Geographical Society of the Pacific, San Francisco.
Journal of the Association of Engineering Societies, St. Louis, Mo.
Journal, The Railroad and Engineering, New York.
Military Service Institution of the U. S., Governor's Island, N. Y.
School of Mines Quarterly, New York City.
Sibley College, Cornell University, Ithaca, N. Y.
Technical Society of the Pacific Coast, San Francisco, Cal.

FOREIGN.

Association Parisienne des Propriétaires d'Appareils à Vapeur, Paris.
Canadian Institute, Toronto.
Giornale d'Artiglieria e Genio, Rome.
Hydrographisches Amt der Kaiserlichen Marine, Berlin.
Institute of Mining and Mechanical Engineers, Newcastle-on-Tyne.
Institution of Civil Engineers, London.
Institution of Mechanical Engineers, London.
Journal de la Marine—Le Yacht—Paris.
Mittheilungen a. d. Gebiete d. Seewesens, Pola.
Norsk Tidsskrift for Sovæsen, Horten, Norway.
North-east Coast Institution of Engineers and Shipbuilders, Newcastle-on-Tyne.
Revista Maritima Brazileina, Rio de Janeiro, Brazil.
Revue du Cercle Militaire Armées de Terre et de Mer, Paris.
Revue Maritime et Coloniale, Paris.
Rivista Marittima, Rome.
Royal Artillery Institution, Woolwich.
Royal United Service Institution, London.
Société des Ingénieurs Civils, Paris.

## SUBSCRIBERS.

"A.," H. M. S. Vernon, care Trübner & Co., London, Eng.
Artillery School, U. S., Fort Monroe, Va.

# ANNUAL REPORT OF THE SECRETARY AND TREASURER.

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TO THE PRESIDENT, OFFICERS AND MEMBERS OF THE INSTITUTE.

*Gentlemen:*—I have the honor to submit the following report of the financial and business transactions of this office during the year ending December 31, 1886. The cash statement is as follows:

ITEMIZED STATEMENT OF RECEIPTS DURING YEAR 1886.

| Source. | 1st Quarter. | 2d Quarter. | 3d Quarter. | 4th Quarter. | Total. |
|---|---|---|---|---|---|
| Dues | $874 03 | $401 00 | $261 96 | $369 00 | $1,905 99 |
| Life-membership fees | 120 00 | 117 00 | 60 00 | 60 00 | 357 00 |
| Subscriptions | 117 75 | 153 50 | 443 80 | 53 60 | 768 65 |
| Sales | 276 77 | 126 15 | 3 00 | 67 50 | 473 42 |
| Extra binding | 22 80 | 2 00 | 1 25 | 4 00 | 30 05 |
| Premium on exchange | 14 | 06 | ........ | ......... | 20 |
| Interest on bonds | 18 25 | 9 00 | 9 00 | 42 64 | 78 89 |
| | $1,429 74 | $808 71 | $779 01 | $596 74 | $3,614 20 |

ITEMIZED STATEMENT OF EXPENDITURES DURING YEAR 1886.

| Item. | 1st Quarter. | 2d Quarter. | 3d Quarter. | 4th Quarter. | Total. |
|---|---|---|---|---|---|
| Postage, freight, telegraphing and incidentals | $69 79 | $37 55 | $30 05 | $48 19 | $185 58 |
| Stationery at H. Q. | 26 30 | 25 | 6 70 | 7 83 | 41 08 |
| Messenger at H. Q. | 60 00 | 60 00 | 60 00 | 85 00 | 265 00 |
| Expenses at Branches | 13 50 | 30 14 | 60 | 11 25 | 55 49 |
| Extra binding | 73 40 | 29 90 | ... .... | ......... | 103 30 |
| Printing publications | 962 83 | 758 04 | 528 28 | 29 00 | 2,278 15 |
| Purchase of back numbers | 50 50 | 9 00 | ...... ... | ......... | 59 50 |
| Prize Essay, 1886 | ......... | 50 00 | 13 75 | 13 83 | 77 58 |
| Advertising | 4 00 | ......... | ......... | ......... | 4 00 |
| Expressage on bonds | ......... | ......... | 1 00 | ......... | 1 00 |
| Purchase of D. C. bonds | 174 75 | 242 25 | ......... | ......... | 417 00 |
| Rebate on sales | ......... | ......... | ... ..... | 10 00 | 10 00 |
| | $1,435 07 | $1,217 13 | $640 38 | $205 10 | $3,497 68 |

| | |
|---|---|
| Balance unexpended from receipts of 1886 | $116 52 |
| Balance on hand January 1st, 1886 | 613 65 |
| Total cash on hand January 1st, 1887 | $730 17 |
| Balance to credit of Reserve Fund (uninvested) | 148 12 |
| Available cash on hand January 1st, 1887 | $582 05 |
| Publisher's bill (not yet rendered) | 536 00 |
| True balance on hand January 1st, 1886 | $46 05 |
| Bills outstanding | None. |
| Bills receivable, outstanding dues 1885 and 1886 | 500 00 |
| Publications sold late in December | 37 50 |
| Assets | $583 55 |

It may be noted here that five numbers have been paid for during the current year, which was one number in excess of the regular issue.

## The Reserve Fund.

On January 1, 1886, there was an uninvested balance of $206.12 to the credit of this fund. During the year 1886 the Institute acquired twelve (12) new life members and fees amounting to $360, thus making a total credit to fund of $566.12. In accordance with the Constitution, a purchase of District of Columbia 3.65 per cent. bonds was made amounting to $418. Face value, $350. Bonds run till 1924. In July last the Treasurer had the $900 in United States 4 per cent. consols and $1000 in District of Columbia 3.65 per cent. bonds registered at the United States Treasury in the name of the U. S. Naval Institute. The registered bonds and $350 in 3.65 per cent. District of Columbia bonds are deposited in the vault of the Farmers' National Bank of Annapolis for safekeeping.

Total face value of bonds in Reserve Fund, $2250. The interest only of this fund is available for current expenses, the principal being held in perpetuity to guarantee the future interests of the Institute, and of the life members in particular.

## Meetings and Publications, 1886.

During the calendar year 1886 nine meetings of the Institute took place at Annapolis, and a number at Washington, New York, Newpor l Norfolk.

rterly publications have, in accordance with the plan the Board of Control, appeared as early in the quarter as

practicable, No. 36 in February, No. 37 in April, No. 38 in July, and finally, No. 39 in December, thus forming a volume (No. XII.) of 661 printed pages (not including appendices, notices and plates).

## Publications on Hand.

The Institute has on hand back publications as follows:

| | Copies Plain. | Copies Bound. | | Copies Plain. | Copies Bound. |
|---|---|---|---|---|---|
| No. 1 | 218 | ... | No. 21 | 245 | ... |
| 2 | 261 | ... | 22 | 289 | ... |
| 3 | 78 | ... | 23 | 200 | ... |
| 4 | 170 | ... | 24 | 218 | ... |
| 5 | 139 | ... | 25 | 1176 | 47 |
| 6 | 20 | ... | 26 | 221 | 77 |
| 7 | 27 | ... | 27 | 307 | 27 |
| 8 | 53 | ... | 28 | 14 | 4 |
| 9 | 57 | ... | 29 | 234 | 27 |
| 10 | 16 | ... | 30 | 264 | 5 |
| 11 | 233 | ... | 31 | 82 | 58 |
| 12 | 73 | ... | 32 | 7 | 184 |
| 13 | 12 | ... | 33 | 27 | 165 |
| 14 | 9 | ... | 34 | 80 | 14 |
| 15 | 5 | ... | 35 | 125 | 67 |
| 16 | 237 | ... | 36 | 265 | 30 |
| 17 | 4 | ... | 37 | 190 | 26 |
| 18 | 106 | ... | 38 | 242 | ... |
| 19 | 122 | ... | 39 | 289 | ... |
| 20 | 140 | ... | | | |

The archive set complete, Vol. I. to Vol. XII. inclusive, bound in full turkey, and seven copies Vol. X. in two parts in half turkey.

JNO. W. DANENHOWER, Lieut., U. S. N.,
*Secretary and Treasurer.*

# CONSTITUTION AND BY-I

### ARTICLE I.—Title.

This organization shall be called the United St

### ARTICLE II.—Object.

Its object is the advancement of professional, lit knowledge in the Navy.

### ARTICLE III.—Headquarte

The Headquarters of the Institute shall be at Naval Academy, Annapolis, Md.

### ARTICLE IV.—Officers.

The officers shall be as follows:

A President.

A Vice-President.

A Board of Control.

A Secretary and Treasurer.

A President and Corresponding Secretary for e

### ARTICLE V.—Election of Off

Sec. 1. There shall be a meeting of the Institu on the second Friday in October of each year, of weeks' notice shall be given, at which meeting officers, except those of Branches, shall be electe session, and a majority of votes given by prese elect; regular or life members only being eligible

Sec. 2. Absent members who have the constitu may vote by proxy at such elections, and in the questions involving changes in the Constitution upon questions involving the expulsion of memb of honorary members. On all other questions actual presence. Life members shall have the f members to vote on every question. Hono

members shall not have the privilege of voting. All proxies must be signed by the member whose vote is to be represented.

SEC. 3. Members elected to the position of officers of the Institute will assume their respective duties at the date from which elected.

SEC. 4. Casual vacancies in the officers of the Institute may be temporarily filled by the Board of Control.

## ARTICLE VI.—DUTIES OF OFFICERS.

SEC. 1. The President shall preside at business meetings of the Institute, or its Branches, at which he may be present.

SEC. 2. In the absence of the President at Headquarters, the Vice-President shall preside.

SEC. 3. The Board of Control shall consist of seven members in good standing, regular or life, and its duties shall be the management of all the financial and administrative business of the Institute, including the censorship, printing, and control of its publications. The Secretary and Treasurer shall be, *ex officio*, a member of the Board, its medium of communication and the recorder of its transactions. The regular meetings of the Board of Control shall be held upon the first and third Saturday of each month. A special meeting shall be called by the Secretary and Treasurer upon the written application of two members of the Board. A quorum shall consist of three members. In the absence of both the President and Vice-President at business meetings of the Institute, a member of the Board of Control shall preside. It shall be the duty of this Board to appoint a committee of three of its own members to audit and certify the books and accounts of the Secretary and Treasurer at least once every quarter.

SEC. 4. The Secretary and Treasurer shall keep a register of the members in which shall be noted all changes; an authenticated copy of the Constitution and By-Laws in force; a journal of the Proceedings of the Institute; a separate journal of the transactions of the Board of Control; a receipt and expenditure book; an account-current with each member. Under the authority of the Board of Control, he shall be the disbursing and purchasing officer of the Institute and the custodian of the funds, securities, and assets, and it shall be his duty to furnish members with receipts for dues paid. He shall attend to all correspondence and keep a record thereof, give due notice of meetings of the Institute and Board of Control, have charge of the stenographer and copyists employed to prepare records of the

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Sec. [illegible] These officers [illegible] associate mem[illegible] [illegible] but [illegible] office [illegible] [illegible]

Sec. [illegible] Associate members and life members [illegible] their [illegible] elected [illegible] made [illegible] secretary [illegible] member [illegible] them, and such [illegible] Board of Control, and if their [illegible] Treasurer shall make known th[illegible]

meeting of the Institute, and a vote shall then be taken, a majority of votes cast by members present electing.

SEC. 8. The annual dues for regular and associate members shall be three dollars, payable upon joining the Institute, and upon the first day of each succeeding January. The fee for life membership shall be thirty dollars, but if any regular or associate member has paid his dues for the year in which he wishes to be transferred to life membership, or has paid his dues for any future year or years, the amount so paid shall be deducted from the fee for life membership.

SEC. 9. No member of the Institute shall be dismissed except by recommendation of the Board of Control, and by a two-thirds vote of the members of the Institute voting at any regular or called meeting, of which at least one month's notice shall be given. Without the recommendation of the Board of Control, no member can be dismissed except by a three-fourths vote. In both the above cases there must be a total vote of at least a majority of all those members entitled to a vote, the voting to be either by presence or proxy. Members two years in arrears shall be dropped. Those dropped for non-payment of dues can regain their membership by paying two years' arrearage of dues, but the Board of Control may adjust any special case upon its merits.

## ARTICLE VIII.—RESERVE FUND.

The amount now invested ($2250) in United States and District of Columbia bonds shall be placed to the credit of a Reserve Fund. All moneys received from life-membership fees shall, as soon as practicable, be invested in United States bonds, or bonds guaranteed by the United States, and shall be added to said fund, which shall be held in perpetuity to guarantee the future interest of said life members. The interest of said fund may, however, be used for the current expenses of the Institute.

## ARTICLE IX.—MEETINGS.

SEC. 1. The regular time of holding meetings of the Institute shall be the second Friday of each month, but if there should be no paper accepted by the Board of Control to be read, professional subject to be discussed, or executive business to be transacted, the monthly meeting may be omitted.

SEC. 2. Special meetings of the Institute shall be called by the Secretary and Treasurer when directed by the Board of Control.

SEC. 3. Notice of regular or special meetings shall state the title of papers to be read, with the name of the author, and mention the executive business that will be brought before the meeting.

SEC. 4. A stenographer may be employed when authorized by the Board of Control.

## ARTICLE X.—PAPERS AND PROCEEDINGS.

SEC. 1. Quarterly, or as much oftener as the Board of Control may decide, the papers read before the Institute and its Branches, together with the discussions growing out of them, shall be published. Papers on intricate technical subjects of such a character as not to be appreciated on merely casual investigation, and articles too extended to be read at one meeting of the Institute, may be published as a part of the Proceedings when authorized by the Board of Control; and there may also be published, under the heads of Editorial and Professional Notes, such comment and information as may be deemed useful to the service.

SEC. 2. One copy of the Proceedings, when published, shall be furnished to each regular, life, honorary, and associate member, to each corresponding Society of the Institute, and to such libraries and periodicals as may be determined upon by the Board of Control.

SEC. 3. Copies of the Proceedings and complete sets may be sold at prices fixed by the Board of Control, and the Board shall also fix the rate of annual subscription for others than members.

SEC. 4. A receipt and expenditure account of the Institute's publications, showing the number on hand, shall be included in the report of the Secretary and Treasurer of each year.

SEC. 5. The Board of Control shall decide the size of the edition of each number of the Proceedings to be published, and also the ...

## ARTICLE XI.—ANNUAL PRIZE ESSAY.

SEC. 1. A prize of at least one hundred dollars, with a gold medal, ... each year for the best essay on any subject selected by the Board of Control.

... award for the above-named Prize shall be made by a ... competent and disinterested judges appointed by the Board, and the time and manner of submitting such essays ... and announced by said Board.

SEC. 3. In the event of the Prize being awarded to the winner of a previous year, a gold clasp, suitably engraved, will be given in lieu of a gold medal.

## ARTICLE XII.—BRANCHES.

SEC. 1. The Board of Control is empowered to appoint Corresponding Secretaries for all Naval Stations, both ashore and afloat, where there is no organized Branch; also for Branches where a vacancy exists owing to the resignation of the Corresponding Secretary before a meeting can be called to elect a successor.

SEC. 2. The officers of a Branch shall be a Vice-President and a Corresponding Secretary.

SEC. 3. The Vice-President shall perform the same duty for the Branch as prescribed for the President of the Institute.

SEC. 4. The Corresponding Secretary of a Branch shall keep a register of the members residing within the limits of the Station, and an account-current with each. He shall keep a journal of the proceedings of the Branch and a copy of the Constitution and By-Laws. He shall give due notice of all meetings of the Branch, and shall have control of the stenographer whenever it is deemed necessary to employ one. He shall forward to the Secretary and Treasurer of the Institute all papers read before his Branch, and keep him informed of all new members and their addresses, and of all business relating to the Institute. He shall have charge of the Branch library and of all books and papers, and shall receive and distribute publications. He shall keep a receipt and expenditure book, shall collect dues from members on the Station and give receipts therefor. He shall be authorized to expend such part of the funds in his possession for stationery, postage, printing, and for other incidental expenses as may be deemed necessary. He shall at the end of each month render to the Secretary and Treasurer a detailed statement of moneys received and expended, with vouchers for expenditures, and shall forward to the Secretary and Treasurer the funds remaining on hand, retaining only sufficient to defray the estimated current expenses of the Branch for the ensuing month.

SEC. 5. Monthly meetings of each Branch may be held upon such dates as the Branch shall decide, but if there is no paper to be read or business to be transacted at the appointed date, the Corresponding Secretary may omit the call for the regular meeting. Special meetings may be called when necessary.

### ARTICLE XIII.—COPYRIGHT.

The Proceedings shall be copyrighted in behalf of the Institute by the Secretary and Treasurer.

### ARTICLE XIV.—AMENDMENTS.

No addition or amendment to the Constitution shall be made without the assent of two-thirds of the members voting; the By-Laws, however, may be amended by a majority vote. Notice of proposed changes or additions shall be given by the Secretary and Treasurer at least one month before action is taken upon them. A total vote equal to at least half the number of regular and life members shall be required.

## BY-LAWS.

### ARTICLE I.

The rules of the United States House of Representatives shall, in so far as applicable, govern the parliamentary proceedings of the Society.

### ARTICLE II.

1. At both regular and stated meetings the routine of business shall be as follows:

2. At executive meetings, the President, or, in his absence, the Vice-President, or, in the absence of both, a member of the Board of Control, shall call the meeting to order, and occupy the chair during the session; in the absence of these, the meeting shall appoint a Chairman.

3. At meetings for the presentation of papers and discussion, the Society shall be called to order as above provided, and a Chairman shall be appointed by the presiding officer, reference being had to the subject about to be discussed, and an expert in the specialty to which it relates being selected.

4. At regular meetings, after the presentation of the paper of the evening, or on the termination of the arguments made by members appointed to or voluntarily appearing to enter into formal discussion, the Chairman shall make such review of the paper as he may deem proper. Informal discussion shall then be in order, each speaker

being allowed not exceeding ten minutes in the aggregate, unless by special consent of the Society. The author of the paper shall, in conclusion, be allowed such time in making a résumé of the discussion as he may deem necessary. The discussion ended, the Chairman shall close the proceedings with such remarks as he may be pleased to offer.

5. At the close of the concluding remarks of the Chairman, the Society shall go into executive session, as hereinbefore provided, for the transaction of business as follows:

1. Stated business, if there shall be any to be considered.
2. Unfinished business taken up.
3. Reports of Officers and Committees.
4. Applications for membership reported and voted upon.
5. Correspondence read.
6. Miscellaneous business transacted.
7. New business introduced.
8. Adjournment.

# NAVAL INSTITUTE PRIZE ESSAYS, 1879–1888.

## 1879.

*Subject:*—"NAVAL EDUCATION.—I. OFFICERS. II. MEN."

*Judges of Award:*—CHARLES W. ELLIOT, President of Harvard University; DANIEL AMMEN, Rear-Admiral, U. S. N.; WM. H. SHOCK, Engineer-in-Chief, U. S. N.

*Winner of the Prize:*—Lieutenant-Commander ALLAN D. BROWN, U. S. N. *Motto of Essay:*—"Qui non proficit."

*First Honorable Mention:*—Lieutenant-Commander CASPAR F. GOODRICH, U. S. N. *Motto of Essay:*—"Esse quam videri."

*Second Honorable Mention:*—Commander ALFRED T. MAHAN, U. S. N. *Motto of Essay:*—"Essayons."

Number of Essays presented for competition, ten.

## 1880.

*Subject:*—"THE NAVAL POLICY OF THE UNITED STATES."

*Judges of Award:*—Hon. WM. M. EVARTS, Secretary of State; Hon. R. W. THOMPSON, Secretary of the Navy; Hon. J. R. MCPHERSON, U. S. Senator.

*Winner of the Prize:*—Lieutenant CHARLES BELKNAP, U. S. N. *Motto of Essay:*—"Sat cito, si sat bene."

Number of Essays presented for competition, eight.

## 1881.

*Subject:*—"THE TYPE OF (I.) ARMORED VESSEL, (II.) CRUISER, BEST SUITED TO THE PRESENT NEEDS OF THE UNITED STATES."

*Judges of Award:*—Commodore W. N. JEFFERS, U. S. N.; Chief Engineer J. W. KING, U. S. N.; Chief Constructor JOHN LENTHALL, U. S. N.

*Winner of the Prize by decision of two of the Judges:*—Lieutenant EDWARD W. VERY, U. S. N. *Motto of Essay:*—"Aut Cæsar, aut nullas."

*Recommended for the Prize by one of the Judges:*—Lieutenant SEATON SCHROEDER, U. S. N. *Motto of Essay:*—"In via virtute via nulla."

Number of Essays presented for competition, four.

## 1882.

*Subject:*—"OUR MERCHANT MARINE; THE CAUSES OF ITS DECLINE AND THE MEANS TO BE TAKEN FOR ITS REVIVAL."

*Judges of Award:*—Hon. HAMILTON FISH, Ex-Secretary of State; JOHN D. JONES, President Atlantic Mutual Insurance Company, New York; A. A. LOWE, Ex-President New York Chamber of Commerce.

*Winner of the Prize:*—Lieutenant JAMES D. J. KELLEY, U. S. N. *Motto of Essay:*—"Nil clarius aquis."

*First Honorable Mention:*—Master CARLOS G. CALKINS, U. S. N. *Motto of Essay:*—"Mais il faut cultiver notre jardin."

*Second Honorable Mention:*—Lieutenant-Commander F. E. CHADWICK, U. S. N. *Motto of Essay:*—"Spero meliora."

*Third Honorable Mention:*—Lieutenant RICHARD WAINWRIGHT, U. S. N. *Motto of Essay:*—"Causa latet: vis est notissima."

*Essay printed by request of John D. Jones, Esq.*—Ensign W. G. DAVID, U. S. N. *Motto of Essay:*—"Tempori parendum."

Number of Essays presented for competition, eleven.

## 1883.

*Subject:*—"HOW MAY THE SPHERE OF USEFULNESS OF NAVAL OFFICERS BE EXTENDED IN TIME OF PEACE WITH ADVANTAGE TO THE COUNTRY AND THE NAVAL SERVICE?"

*Judges of Award:*—Hon. ALEXANDER H. RICE; Judge JOSIAH G. ABBOTT; Rear-Admiral GEORGE H. PREBLE, U. S. N.

*Winner of the Prize:*—Lieutenant CARLOS G. CALKINS, U. S. N. *Motto of Essay:*—"Pour encourager les autres."

*First Honorable Mention:*—Commander N. H. FARQUHAR, U. S. N. *Motto of Essay:*—"Semper paratus."

*Second Honorable Mention:*—Captain A. P. COOKE, U. S. N. *Motto of Essay:*—"Cuilibet in arte suâ credendum est."

Number of Essays presented for competition, four.

## 1884.

*Subject:*—"THE BEST METHOD FOR THE RECONSTRUCTION AND INCREASE OF THE NAVY."

*Judges of Award:*—Rear-Admiral C. R. P. RODGERS, U. S. N.; D. C. GILMAN, LL. D., President of the Johns Hopkins University; Hon. J. R. HAWLEY, U. S. Senator.

*Winner of the Prize:*—Ensign W. I. CHAMBERS, U. S. N. *Motto of Essay:*—"Thou too, sail on, O Ship of State."

Number of Essays presented for competition, two.

## 1885.

*Subject:*—"INDUCEMENTS FOR RETAINING TRAINED SEAMEN IN THE NAVY AND THE BEST SYSTEM OF REWARDS FOR LONG AND FAITHFUL SERVICE."

*Judges of Award:*—Rear-Admiral THORNTON A. JENKINS, U. S. N.; Commander W. S. SCHLEY, U. S. N., Chief of Bureau of Equipment and Recruiting, Navy Department, Washington, D. C.; and Captain JOHN CODMAN, of New York City.

*Winner of the Prize:*—Commander NORMAN H. FARQUHAR, U. S. N. *Motto of Essay:*—"Ut prosim."

Number of Essays presented for competition, three.

## 1886.

*Subject:*—"WHAT CHANGES IN ORGANIZATION AND DRILL ARE NECESSARY TO SAIL AND FIGHT MOST EFFECTIVELY OUR WAR SHIPS OF THE LATEST TYPE?"

*Judges of Award:*—Rear-Admiral E. SIMPSON, U. S. N., President of Board of Inspection; Captain MONTGOMERY SICARD, U. S. N., Chief of Bureau of Ordnance; and Captain AUGUSTUS P. COOKE, U. S. N., Commanding U. S. R. S. Vermont.

Number of Essays presented for competition, seven.

These Essays are now in the hands of the Judges, and the award will soon be made.

## 1887.

*Subject:*—"THE NAVAL BRIGADE—ITS ORGANIZATION, EQUIPMENT, AND TACTICS."

## 1888.

See Special Notice on last page.

# PROCEEDINGS

OF THE

# UNITED STATES NAVAL INSTITUTE,

*ANNAPOLIS, MD.*

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# PROCEEDINGS

OF THE

UNITED STATES

# NAVAL INSTITUTE

VOLUME XIII.

PUBLISHED QUARTERLY BY THE INSTITUTE.

ANNAPOLIS, MD.

[illegible] U. S. NAVAL INSTITUTE

## NOTICE.

The U. S. Naval Institute was established in 1873, ... advancement of professional and scientific knowledge ... enters upon its fifteenth year of existence, trusting ... support to the officers and friends of the Navy. The ... Control earnestly invite the cooperation and aid of the ... of others interested in the Navy, for the advance of the ... the contribution of papers and communications upon ... naval profession, as well as by personal support and ...

On the subject of membership the Constitution reads:

### ARTICLE VII.

SEC. 1. The Institute shall consist of regular, life ... members.

SEC. 2. Officers of the Navy, Marine Corps, and all ... the Naval Service, shall be entitled to become regular ... shall, on payment of dues ... to the Secretary ... Corresponding Secretary of a Branch. Members who ... subsequent to joining the Institute will be regarded ... described in this Section.

SEC. 3. The Prize Essayist of each year shall be ... payment of fee.

SEC. 4. Honorary members shall be selected from ... Military Officers, and from eminent men of learning in ... of the Navy shall be, *ex officio*, an honorary member ... exceed thirty (30). Nominations for honorary mem... reported by the Board of Control, and a vote equal to ... regular and life members, given by proxy or presence ... electing.

SEC. 5. Associate members shall be elected from ... Revenue Marine, foreign officers of the Naval and ... from persons in civil life who may be interested ... Institute.

SEC. 6. Those entitled to ... associate memb... members, provided that the number of Branch ... Marine Corps ... one hundred ...

SEC. 7. Associate members and life members, other ... regular members, shall be elected as follows: Nom... in writing to the Secretary and Treasurer, with the name ... thereof and such communications shall be ... of their report ... the Secretary and Treasurer ... result at the next meeting of the Institute, and a vote ... majority of votes cast by members present electing.

The Proceedings are published quarterly, and may be ... bers upon application to the Secretary ... In case ... fees ... of ...

Single copies of the Proceedings ... Back num... and ... Secretary and Treas...

Annual subscription ... $3.50. Annual ... associate members $3.00. Life membership fee $30.0...

### FORM OF BEQUEST.

I give and bequeath to the ... the ... INSTITUTE ... October 18, 1873, at Annapolis, Md., ... to be applied to the uses and purposes of said Associa...

If real estate is bequeathed, describe it.